the glass industry

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A.C.S. Will Observe 60th Anniversary at Annual Meeting in Pittsburgh

• THE ANNUAL AMERICAN Ceramic Society Meeting will take place in Pittsburgh, Pa. starting April 27th and will run through May 1st.

The place has been appropriately chosen since at this meeting the Society will observe its 60th anniversary and it was in Pittsburgh that the idea of this organization of glass and ceramic scientists first began.

To commemorate this milestone in the Society's history, a plaque has been made of photosensitive glass which will be mounted on the wall of the building that now occupies the site where the old Monongahela House once stood, the hotel where the idea of a ceramic society had its inception.

The plaque will come from Corning Glass Works and was prepared under the supervision of Dr. S. D. Stookey.

J. S. Nordyke of Hammond Lead Company, A.C.S. vice president, will preside at the brief dedication ceremonies on Sunday afternoon, the 27th, at 1:30 P. M.

More than two thousand members are expected to attend the technical sessions and participate in the full program which has been planned.

"Meteorites, Satellites, and Ceramics" will be the subject of the Edward Orton, Jr. Memorial Lecture, to be delivered by Dr. John S. Rinehart, assistant director of the Smithsonian Institution's Astrophysical Observatory. Dr. Rinehart is a widely recognized authority on conditions in outer space.

Speaker for the annual banquet will be Carl N. Jansen, a leader in the campaign that has changed Pittsburgh from a smoky, sooty city to one of charm and beauty. He will speak on "Pittsburgh's Renaissance".

The first meeting of the newly organized Electronics Division will be held as a part of this Pittsburgh meeting, with Dr. John Koenig of Rutgers as chairman and W. W. Coffeen of Metal & Thermit Corporation as program chairman. It has 30 papers listed for presentation.

The largest number of papers is for the Basic Science Division with 41 on its program. The Refractories Division is a close second with 39 papers for presentation.

The Glass Division has scheduled a minimum number of papers, only fifteen; it is hoped that in this way more open discussion during the sessions will prevail.

Among the special features which will take place is the presentation of the new John Jepson gold medal. Other honors planned for the Monday morning general session will be the elevation of twenty-four members to the stature of Fellows of the Society, the Ross Coffin Purdy Award, and Honorary Member, the highest honor of the American Ceramic Society.

The annual Student Speaking Contest, with Robert L. Stone of the Universtiy of Texas in charge, is sched-

Cover

It was during the 12th Annual Convention of the National Brick Manufacturers Association in the Monongahela House in 1898 that the idea of a scientific-ceramic society was conceived.

Four of the more technically minded members, Elmer E. Gorton, Samuel Geijsbeck, Edward Orton and Albert V. Bleininger, recognizing the need for a scientific approach to the glass and ceramic industries' problems canvassed the convention and managed to obtain enough support to warrant pursuing the idea.

A year later in 1899 the first meeting of the American Ceramic Society was convened with fifteen members attending and a total of nineteen charter members signed up. Well over two thousand members are expected to be on hand for the 60th Anniversary Meeting.

uled as a Sunday event, as is a meeting of the National Institute of Ceramic Engineers. The Society's annual reception will be held in the evening at which members of the Pittsburgh Section will serve as informal hosts.

The annual jamboree Monday night will be known as the Pittsylvania Party.

The idea is borrowed from Pittsburgh's historic past when there was a movement for the creation of a new state centering around the Pittsburgh area to be known as Pittslyvania.

The Monday night events will include a buffet dinner, a big floor show, and a dance.

Following these days of technical sessions by the nine Divisions the meeting will conclude with plant tours on Thursday. A dozen tours are planned in order to take advantage of the wide variety of industries of glass and ceramic interest around Pittsburgh. Arrangements for the plant trips are being made by H. P. Bonebrake of the Aluminum Company of America.

John F. McMahon, dean of the College of Ceramics at Alfred University, will preside over the 60th Annual Meeting and he will induct into the presidency his successor, Richard S. Bradley of A. P. Green Fire Brick Company.

N. M. Brandt

Neil M. Brandt of Mellon Institute will be installed as Glass Division Chairman. Vice-Chairman will be Frank R. Bacon of Owens-Illinois. Fay V. Tooley, University of Illinois, will continue as Division Secretary.

Following is the list of papers in the order of their presentation to be given at the Glass Division sessions:

1. The Use of Ceramics in Electroluminescent Light Sources. R. M. Rulon and David L. Cole, Sylvania Electric Products, Inc., Salem, Mass.
2. Sylvatrons: Electroluminescent Solid State Devices for Visual Information Display. R. M. Rulon, Sylvania Electric Products, Inc., Salem, Mass.
3. Some New Inorganic Glasses Fluid Below 400° C. S. S. Flaschen and A. D. Pearson, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
4. Silicone Advances in Glass Container Manufacture. J. A. Stapp, Silicones Division, Union Carbide Corporation, Tonawanda, N. Y.
5. Exploration of Lithia Glass Forming Systems. I. Li_2O-$Al_2O_3SiO_2$ with 0 to 30.0 Per Cent CaO Additions. H. W. Rauch, C. H. Commons, Jr., and H. H. Blau, Foote Mineral Company, Berwyn, Pa.
6. The Effect of Temperature Gradients and Aspect Ratio on Viscous Flow Through Open Channels. A. R. Cooper, Jr., Massachusetts Institute of Technology, Cambridge, Mass.
7. Viscous Flow of Glasses and Relation to Visco-Elastic Effects. H. T. Smyth, Rutgers University, New Brunswick, N. J.
8. On the Internal Structure of Borosilicate Glass by Electron Microscopy. M. Watanabe and H. Noake, Preston Laboratories, Inc., Butler, Pa.
9. The Effect of Temperature on the Strength and Static Fatigue of Glass. R. E. Mould, Preston Laboratories, Inc., Butler, Pa.
10. Attack of Glass by Chelating Agents. F. M. Ernsberger, Glass Division, Research Laboratories, Pittsburgh Plate Glass Company, Creighton, Pa.
11. The Solubility of Silica in Nitric Acid Solutions. T. H. Elmer and Martin E. Nordberg, Glass Research and Development Laboratory, Corning Glass Works, Corning, N. Y.
12. New Uses for Flotation in Glass Technology. C. H. Greene, Alfred University, Alfred, N.Y.
13. Activities and Structure of Some Melts in the System Na_2O-SiO_2. W. J. Knapp and W. D. Van Vorst, University of California, Los Angeles, Cal.
14. Relations Between Rate of Stress Release and Viscosity in Soda-Lime, Potash-Barium and Borosilicate Glasses. D. A. McGraw and C. L. Babcock, Owens-Illinois Glass Company, Toledo, Ohio.
15. The Evaluation of Several Infrared Transmissive Glasses. R. B. Grekila and H. D. Root, Westinghouse Electric Corporation, Pittsburgh, Pa.

LABOR-INDUSTRY CONFERENCES URGED

A series of conferences designed to avert any recession in the glass container industry has been proposed by Lee W. Minton, international president of the Glass Bottle Blowers Association, AFL-CIO. Minton has sent telegrams to Mr. A. J. Martin, Director of Labor Relations, Glass Container Manufacturers Institute, with copies to the heads of more than forty glass container companies, urging that the Institute and the Union's Negotiating Sub-Committees meet periodically in 1958 to develop programs for keeping employment and production at their present high levels.

"This is not the time," Minton wired, "for our industry, or others, to become pessimistic and overlook our potentialities. By working together for a healthy and prosperous industry, we will be a source of encouragement to other industries and to our nation as a whole."

Mr. Martin replied noting the recommendation calling for sub-committee meetings "had merit" and that he would "recommend favorable consideration."

Although workers in the glass container industry are protected by a three-year contract guaranteeing annual wage increases, Minton warned that both management and labor had to meet the responsibility of protecting the well-being of the industry.

To date, the glass container industry has not been seriously affected by the current business recession. Production levels are at an all-time high, last year's output exceeding twenty billion bottles and jars. The industry is 100 per cent unionized, and labor-management relations are excellent. "This level must be maintained," Minton said.

Use of X-Ray Methods for Investigations of Glass Structures

By KAI GRJOTHEIM, Department of Inorganic Chemistry,
The Technical University of Norway, Trondheim, Norway

SUMMARY

The x-ray method of investigating glass structures is discussed, and the different sources of error are specially stressed. It is concluded that the power of the x-ray method in its present state of development has been somewhat overestimated.

I. INTRODUCTION

DEBYE-SCHERRER X-RAY diagrams of glass do not give discrete lines, as obtained from crystalline substances. Instead one obtains broad, diffuse bands [1]. This is a characteristic property of glass.

Former attempts at analyzing such diffuse diffraction patterns were based on the same principles as for the crystal diffraction. It was then proposed to explain the diffuse bands as reflections from planes. The distance between the planes was calculated from Bragg's formula in the same way as for crystals.

Although there is a distinct difference between the sharp line-diagram of a typical crystal powder, and the diffuse band-diagram of a glass, however, there is no sharp dividing line from the one to the other. If the particles in the crystal powder are constantly diminished, the widths of the lines composing the powder diagram will increase and, having sufficient small particles, the line diagram will assume the diffuse character that is typical of band diagrams of glass.

From these facts followed other methods of interpreting the x-ray diagrams of glass.

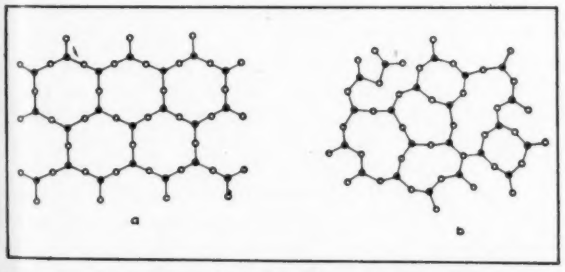

Fig. 1. A two-dimensional outline of the difference in atomic structure of a crystalline (a) and a noncrystalline modification (b) of a Me_2O_3 type substance. In structure (b) only a local order exists around each atom.

Some draw from this the conclusion that x-ray analysis proves glass to consist of a large number of extremely small crystals. It is possible, however, from the width of the lines or bands in the x-ray diagrams to calculate the average diameter of the particles. An examination of the glass diagrams will then give very small particle diameters. In quartz-glass, for instance, the average diameter of the particles is found to be about 7.7 Å [2] But, remembering the fact that the longest side-edge of the cristobalite elementary cell is about 7.0 Å, it is not very reasonable to presume that quartz-glass is composed of small crystals.

By assuming that there exists a little degree of short range order in glass and other non-crystalline media, however, an explanation of the diffuse band-diagram is given [3] (Fig.1). Short range order can be established in the circumference of the various atoms in the non-crystalline modification, by each atom having its nearest neighbors at constant distances, in the same way as in the crystal. While there exists periodical order in the crystal, however, in the model of the glass there is no long range order.

II. THEORY

As early as 1915, Debye [4] and Ehrenfest [5] proved theoretically that diffuse band diagrams with several maxima and minima can be obtained, if there are some interatomic distances occurring repeatedly in the structure of a non-crystalline medium, but lack of regularity in the structure of the glass makes it only possible to determine the numerical value of the interatomic vectors from the observed intensity, and not their direction. This can be shown by a so-called radial density function. In a somewhat popularized form, this function can be said to represent the probability distribution of atoms around an arbitrarily chosen atom in the system.

In the present outline, it is not intended to give a detailed discussion of the mathematical deduction of the distribution function, based on the observed x-ray diffraction intensities of glass. Only a mere sketching of the mathematical formulation of x-ray diffractions from non-crystalline media will be indicated. Following this, some difficulties and instances of uncertainty connected with x-ray investigations of glass will be discussed.

Debye showed that, when monochromatic x-rays of wavelength λ are diffracted in a non-crystalline collection of atoms, the intensity of the coherent radiation, being diffracted at an angle of 2ν to the primary ray, is given as a function of ν by the following expression:

$$I_{coh} = \Sigma_m \Sigma_n f_m f_n \frac{\sin(sr_{mn})}{sr_{mn}}$$

Wherein $s = \frac{4\pi \sin \nu}{\lambda}$. The double summation is taken over all pairs of atoms in the assemblage. r_{mn} is the magnitude of the vector separating the two atoms m and n, and f_m and f_n are the respective atomic scattering fac-

Dr. Grjotheim prepared this paper during his association with the Department of Metallurgical Engineering, University of Toronto, Toronto, Canada.

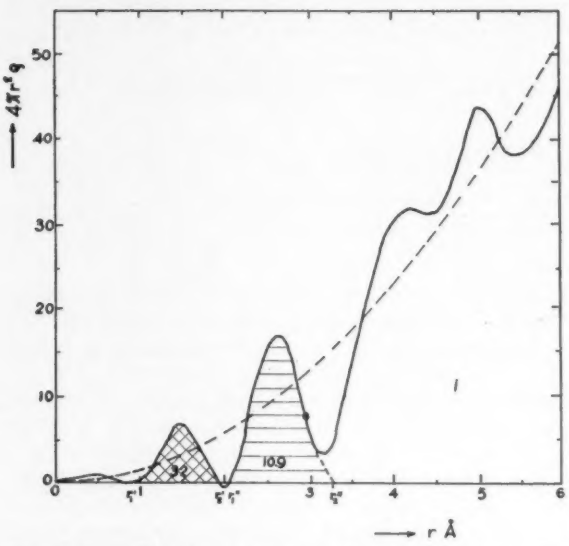

Fig. 2. Example of a monatomic distribution curve. The distribution curve $4\pi r^2 \zeta(r)$ is of carbon black.

tors of these two atoms. These factors show that the scattered x-ray intensity of an atom depends upon the number of electrons present in the electron shell of the respective atom, as well as upon the distribution in space of the electrons in relation to the scattering angle. In calculations, the atomic scattering factors can be taken directly out of tables, as can functions of s for each kind of atom.

A non-crystalline medium, consisting of only one kind of atom, will give a Debye formula:

$$I_{coh} = Nf^2 \left(1 + \Sigma_m \frac{\sin(sr_{mn})}{sr_{mn}}\right)$$

where N stands for the total number of atoms present in the system. Nf^2 will then become the part of the coherent scattered intensity due to reciprocal action between electrons in the same atom. This is also called the structure independent coherent scattering, and it will produce a smooth scattering curve. The second term stands for the intensity due to interference caused by scattering from electrons in different atoms in the system. In a structure determination, this is therefore the significant term, and it is called the structure-dependent coherent scattering.

An analysis of the structure of a non-crystalline medium can be done by calculating, by means of Debye's formula, the theoretical intensity functions from the different presumed structure models. The calculated intensities are then compared to the experimental ones. This laborious "trial-and-error" process was applied with various degrees of success to the first x-ray investigations of non-crystalline media.

In 1927, however, Zernicke and Prins[6] proved that for monoatomic non-crystalline media it was possible to get a radial atomic distribution curve without any a priori assumptions about the structure. This was attained by making a Fourier transform of the experimental intensity functions.

Zernicke and Prins introduced in this formula the continuous atomic distribution function $\zeta(r)$, in which the summation is replaced by an integration:

$$I_{coh} = Nf^2 \left(1 + \int_0^\infty 4\pi r^2 (\zeta(r) - \zeta_0) \frac{\sin sr}{sr} dr\right)$$

$4\pi r^2 \zeta(r)dr$ gives the number (a weighed mean) of atoms present in a spherical shell of radius r and thickness dr. An arbitrarily chosen atom of the system is serving as center of the shell. This expression of the intensity can, by means of the Fourier integral theorem, be directly transformed. If, in addition, the mean atomic density ζ_0 (which is independent of r) is introduced, taking the Fourier transform will give:

$$4\pi r^2 \zeta(r) = 4\pi r^2 \zeta_0 + \frac{2r}{\pi} \int_0^\infty s \frac{I(s)}{Nf^2} \cdot \sin(rs)\, ds$$

where I(s), as will be seen later, can be experimentally determined. Thus, we have a formula giving the atomic density at a distance r, containing only known quantities.

Plotting this function, using r as abscissa, will result in a curve alternating around a parabola representing the mean atomic distribution (Fig. 3)[7]. The maxima of this curve correspond to often-occurring interatomic distances. As a principle, this curve cannot extend below the abscissa axis, as this would give a negative atomic density. Another way of presentation is to plot the difference between the common radial distribution curve and the mean distribution. Thus is produced a curve oscillating about the abscissa axis.

The peaks of the radial atomic distribution curve yield the distance between the atoms, as well as a theoretical possibility of determining the co-ordinate numbers n. This is so, because the integral:

$$n = \int_{r_1}^{r_2} 4\pi r^2 \zeta(r)dr$$

must express the number of atoms between the spheres of radius r_1 and r_2, respectively, an arbitrarily chosen atom in the system being center of the spheres. Measuring the area beneath this curve, lying between r_1 and r_2, that is the points of intersection of the peak of the curve (if necessary being lengthened) and the abscissa axis, will give directly the co-ordinate number n (Fig. 2.). Debye's intensity formula applies to polyatomic media too, but the angular dependence of the scattering from different kinds of atoms not being the same, an exact Fourier transform is no longer possible. Warren[8] handled this difficulty by assuming that the angular dependence of the atomic form factor is equal for all kinds of atoms. When the elements are not too far from each other in the periodic system, this is a reasonable approximation.

This approximation can be expressed mathematically by assuming that the atomic form factor f_m of the atom m can be equalled to a function of the mean scattering factor f_e of a single electron, in this way:

$$f_m = K_m f_e$$

where $f_e = \frac{\Sigma_m f_m}{\Sigma_m Z_m}$ and Z_m is the atomic number of the atom. Thereby K_m is taken to express the effective number of electrons per atom of the type m. This is why K_m often is called the "effective" atomic number. As f_m is a function of s, K_m also will be a function of s, but

in the calculations, a mean value of K_m in the actual s-interval is used.

If the scattering ability of polyatomic media refers to the single electron, it is also necessary to refer the radial density function g(r) to the electrons. When this function is introduced in Debye's scattering formula, and the Fourier transform is accomplished, the result is Warren's expression of the electronic density distribution of polyatomic media:

$$4\pi r^2 \Sigma_m K_m g_m(r) = 4\pi r^2 g_o \Sigma_m K_m + \frac{2r}{\pi} \int_o^\infty \frac{I(s)}{\Sigma_m f_m 2} s \sin(rs)\, ds$$

where g_o is the mean electronic density (independent of r) and the summation is taken over one formula unit (for instance in the case of B_2O_3, over 2 B and 3 O-atoms).

As we have seen, a theoretical calculation of a radial distribution curve, by means of the observed intensity and known tabulated quantities, is possible in the case of polyatomic media too. The radial distribution curve thus obtained will give a sum of the distribution of matter around all atoms in the structure. An often-occurring atomic distance will be shown as a maximum in the radial distribution curve, and the area under this maximum will be a measure of the number of atoms in this distance. Both the interpretation of the distribution curve and the calculation of the co-ordination numbers, however, is more complicated for polyatomic media than for monoatomic.

III. DISCUSSION OF ANALYTICAL PROCEDURE AND ERRORS

In this way then, the x-ray method gives both the atomic distances and the co-ordination numbers of glass. But, during the computation procedure from the x-ray exposure to the calculated radial distribution curve, rather large errors are easily introduced. Usually the effect of these errors is to introduce false peaks in the distribution curve, and a change in the height of the real peaks. The interpretation of distribution curves obtained with the usual methods can thus easily lead to incorrect results, especially in the determination of co-ordination numbers. Using mainly the x-ray investigations on boron oxide glasses of Warren and co-workers as an example, we will try to demonstrate this by considering the features of the different stages in x-ray analysis and discussing the more important sources of error.

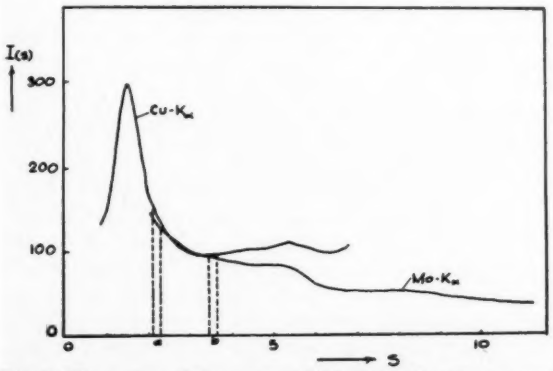

Fig. 3. The curve of the scattered intensity of a 86 per cent phosphoric acid solution, Cu- and Mo- radiation, corrected for absorption and polarization.

Table 1

Intensity Symbols

I_{obs} = observed intensity (function of s)
$I_{total} = I_{obs}$ (corrected for polarization and absorption)
$I_{total} = I_{incoh} + I_{coh}$
I_{incoh} = incoherent scattered intensity
I_{coh} = coherent scattered intensity
I_{coh} = independent + dependent coherent scattering
$\Sigma_m f_m^2$ (s) = the structure independent coherent scattering
(=Nf^2 (s) in the case of monatomic media)
$B(s) = I_{incoh} + \Sigma_m f_m^2$ (s) = the background scattering
= total independent scattering
$I(s) = I_{total} - B(s)$ = the structure dependent coherent scattering

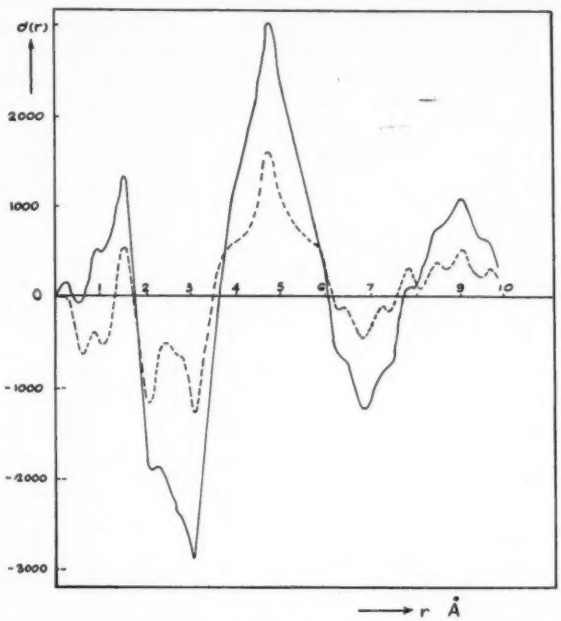

Fig. 4. ζ (r)-curves for the two limiting cases of overlap of Cu- and Mo-intensity curves of 86 per cent phosphoric acid solution.

For x-ray exposures of glass preparations, it is usual to use a powder camera. The observed intensities, I_{obs}, are obtained by converting the photometer curves of the films to a log-scale, and by correcting for polarization and absorption, using tabulated values, I_{total} is obtained (Table 1). The accuracy of intensities obtained by this method is generally estimated to be not better than ± 5 per cent.

To get x-ray diagrams covering the greatest possible angular field, it is usual to expose both with radiation from Cu and Mo. A great inaccuracy is then easily introduced at the linking together of the intensity curve from the Cu- and the Mo- exposure, respectively. This source of error, due to the circumstances of absorption, is thoroughly discussed by Bastiansen and Finbak[9] in x-ray investigations of liquids. As an example, we will look at the two intensity curves from their investigation of a phosphoric acid solution.

As will be seen from Fig. 3, both curves cover the angular field from s = 2 to s = 7, but to make the two intensity curves overlap in the whole field is impossible. Bastiansen and Finbak have chosen an upper and lower limit of overlapping, and calculated the two distribution curves δ (r), thereby obtained. The curves are given in Fig. 4.

From Fig. 4, it is evident that the positions of the peaks along the abscissa are very little influenced by the different choices of overlapping of the Cu- and Mo-curves. The height of the peak and therefore the area determining the co-ordination number, on the contrary, will depend upon the field of overlapping.

After having matched together the Cu- and Mo-curves, Warren et al [8] arrived at the curve of the total intensity of boron oxide glass over an angular field from s = 0.6 to s = 11.4. This curve comprises both the coherent and incoherent radiation. The coherent scattering can, as we earlier have seen, be split into the following two terms: the structure independent and the structure dependent scattering. In structure investigations, it is, as mentioned, only the last term which is of any interest. The intensity of their coherent scattered ray is not of any use either, as this will not give interference. The sum of the two structure independent intensity contributions is called the background scattering, or just the background, and is denominated B(s). This can be

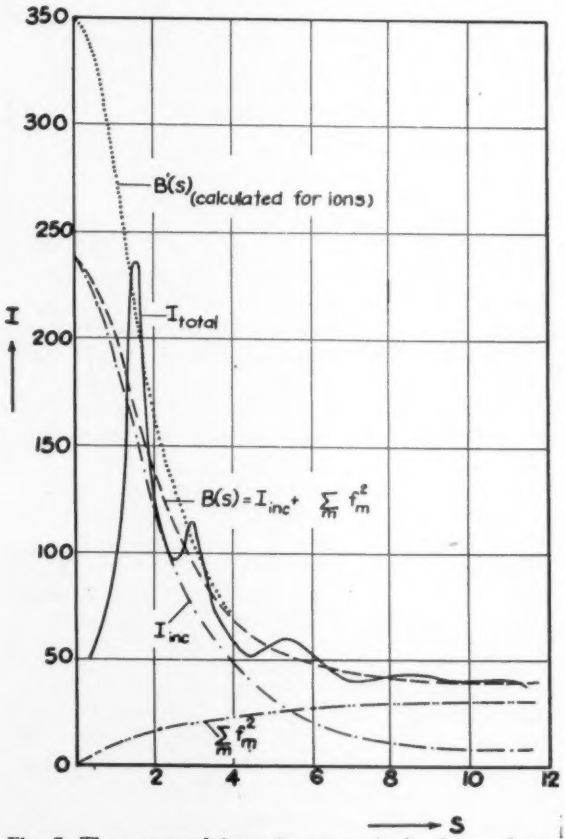

Fig. 5. The corrected intensity curve (—) of pure boron oxide glass with a theoretical background (– – –) calculated for neutral atoms. (The structure independent coherent scattering –.–.–) and the incoherent scattering (–..–..–) are shown.

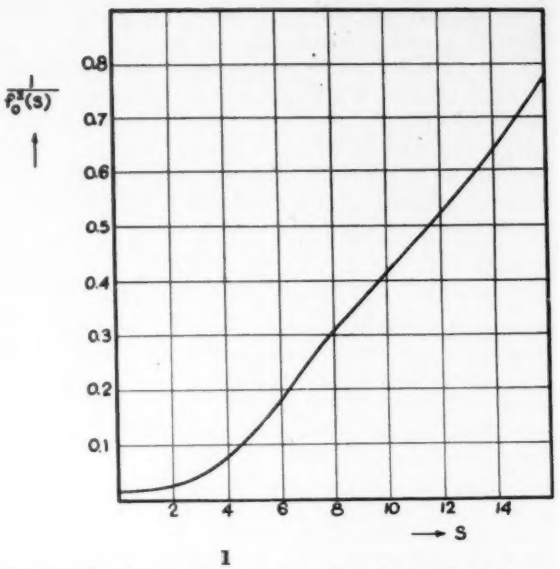

Fig. 6. The factor $\frac{1}{f^2(s)}$ plotted against s for oxygen.

calculated from tables, but is only known approximately. Actually, it corresponds to the scattering of the atoms in a hypothetical gaseous state, where each atom has the same electronic state as in the glass. This electronic state depends upon the chemical bondings in the glass, and naturally these are not exactly known. Usually tabulated values of the scattering of the neutral atoms are used in the calculation of the background. The scattering from the pure ions could be used as another extreme case.

In the calculation of the radial distribution function, it will make appreciable difference whether the background scattering is calculated for ions or neutral atoms [10] (Fig. 5). Something intermediate would probably be the best choice. No correction, however, is generally made for this, and neither is it done in the various published investigations of boron oxide glasses.

Also, other uncertainties are connected with this part of the analysis. The theoretical calculated background and the total intensity are not given in the same scale. Hitherto, the two curves have usually been transformed to the same scale by adjusting, for larger s', the curve of the total intensity to the background curve as well as possible (Fig. 5). It is then assumed that the intensity for larger s mainly is due to the background scattering. This is not quite a satisfactory method of adjusting the relative intensity curve to the background curve. For larger values of s, a possible misadjustment of the background gives rise to a relative error in the difference $I(s) = I_{total} - B(s)$ of appreciable magnitude. Gingrich [11] has shown for liquid argon that, by different adjustments of the total intensity curve to the background, the area of the first peak on the radial distribution curve, relating to the co-ordination number of the first co-ordination sphere, will vary approximately 10 per cent. In polyatomic media, this will give an even greater percentage uncertainty in the determination of co-ordination numbers, because of a corresponding change of the area of the peaks.

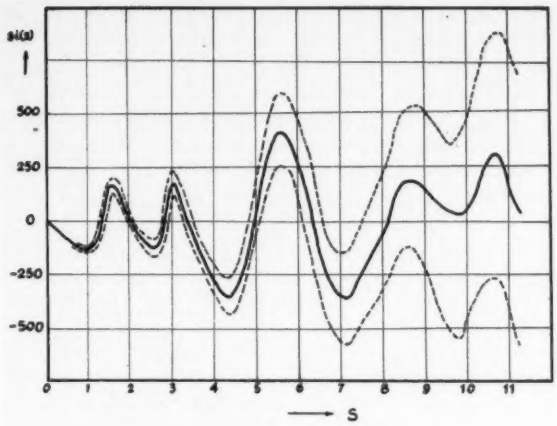

Fig. 7. The reduced intensity curve s. i(s)

$$\left(= s\,\frac{I_{total}\text{-}B(s)}{\sum_m f_m^2} = \frac{s}{\sum_m f_m^2}\,.\,I(s) \right)$$ **calculated from the work of Warren and co-workers. The two dashed curves show the influence of ± 5 per cent uncertainty in the intensity measurements.**

The next step in the calculation is to multiply I(s) by the factor $\Sigma_m f_m^2$ (s). This factor will largely increase with s, not in the least because of the denominator. The factor $\frac{1}{f^2(s)}$ for oxygen is plotted against s in Fig. 6[12].

It is evident that the factor emphasizes the intensity curve for larger values of s out of proportion to its relative accuracy. Consequently, the errors already introduced in the intensity will easily be exaggerated at the largest values of s and greatly influence the final radial distribution curve. The formerly mentioned 5 per cent error limits in I_{total}, after subtracting the background and multiplying by $\Sigma_m f_m^2$ (s), are plotted in Fig. 7. The relative error limits are seen to have increased appreciably. If the uncertainty caused by the linking together of the Cu- and Mo-curves, the correction for the background curve, and the uncertainty in the adjustment of this had been introduced, the picture would have been even worse.

Having calculated the integrand, we reach the final determination of the atomic distribution function. As a principle, it is impossible to calculate this function (compare formulas), as the integration should be taken from zero to infinity, while the intensities can only be

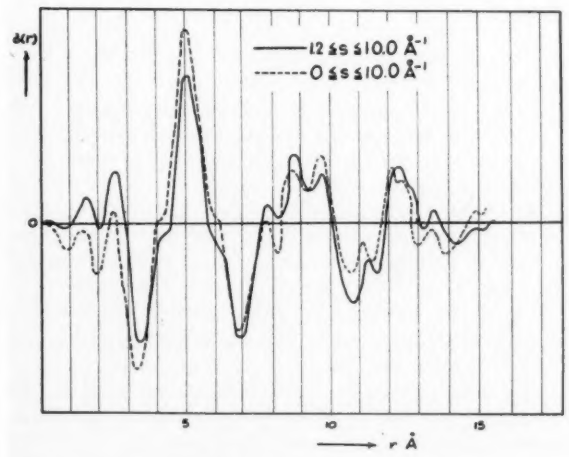

Fig. 8. An experimental δ (r)-curve which gives an example of the influence of different inner integration limits of the intensity curve.

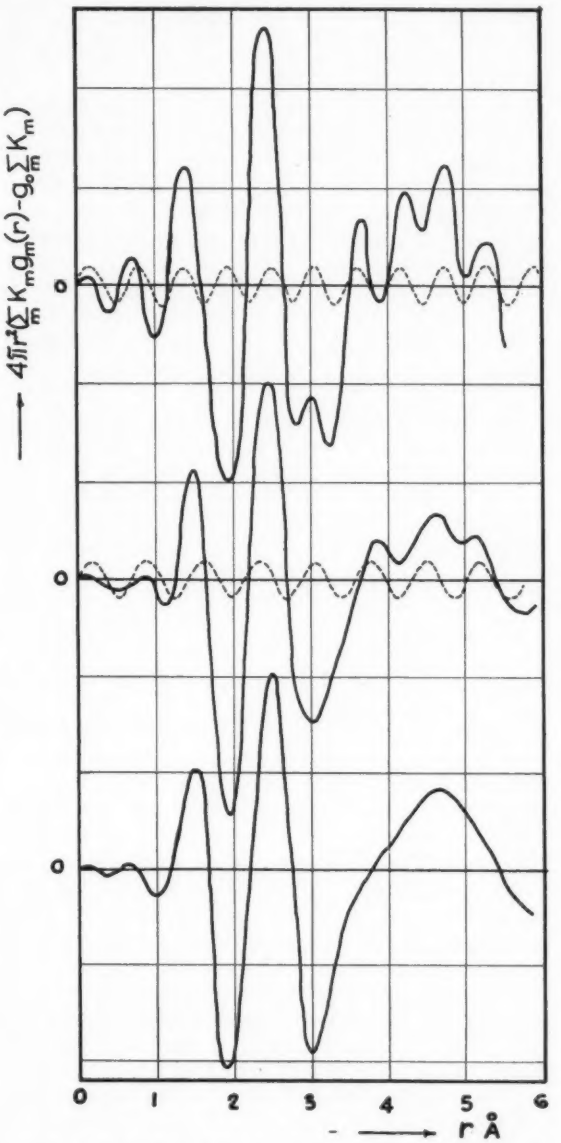

Fig. 9. $\Sigma_m K_m 4\pi r^2 (g_m(r)\text{-}g_o)$ of boron oxide glass after data from Warren and co-workers. The three curves represent, from above: 1) termination at s = 11.4 with superimposed error ripple of wavelength $\frac{2\pi}{10.7}$ = 0.72 A, 2) termination at s = 8.0 and ripple $\frac{2\pi}{8.7}$ = 0.72 A, 3) termination at s = 8.0.

measured in a limited interval. By choosing different limits of the inner portion of the curve, Finbak[13] has demonstrated that these limits are of little importance for the positions along the abscissa of the peaks on the distribution curve. The areas of the peaks, on the other hand, can be strongly affected by the inner field. Fig. 8 shows an example, two δ (r)-curves from an investigation of Tönnesen[14] et al, which illustrate the influence of the inner intensity field upon an experimental δ (r)-curve. The lower integration limit is $s = 1.2$ and 0, respectively, with a presumed intensity curve down to $s = 0$. As will be seen, the positions of the peaks along the r axis are not very much influenced by a change of the lower integration limit, while the heights of the peaks are appreciably changed.

It is mentioned by Finbak[15] that, under especially unlucky circumstances, a peak height can be increased or reduced by 50 per cent or even more, as the upper or lower limit is chosen for the intensity field at $s = 0$. The average influence on the peak height will, according to Finbak, be about $\pm$ 30 per cent. In this estimation, the uncertainty following from the fact that it is not correct for glass to calculate the background on the basis of the neutral atoms, is not considered. As we have seen earlier, this source of error will have its greatest influence in the intensity interval of s near to zero.

The effect of the termination of the integration, or more correctly the practically performed summation at a finite upper limit instead of an infinite one, is that a systematical error is introduced. It is called the termination error, and was first pointed out by Bragg and West[16]. This difficulty is present in all Fourier syntheses. Finbak[13] has shown that a series of investigations of liquid structures has not succeeded, chiefly due to this error. There is another error[13], however, often dominating the termination error.

The mathematical expression of the radial distribution curve shows that an error in the intensity measurement at a scattering angle corresponding to s_x, will produce a ripple in the radial distribution curve with a period of $\frac{2\pi}{s_x}$. As discussed above, errors for large values of s are relatively magnified. Thus, if the outer peak in the intensity curve is not of correct magnitude, a periodic ripple in the radial distribution curve corresponding to this intensity peak will arise.

In the intensity curve of boron oxide glass, from the work of Warren et al (Fig. 5), the outer intensity peak occurs at $s_x = 10.8$ just before the termination at $s = 11.4$. If we compare the intensity curve and the background of the outer field of s, the height of outer peaks indicates an error. And a periodic ripple corresponding to $s = 10.7$ really appears – i.e., with a wavelength of $\frac{2\pi}{10.7} = 0.58$ Å.

Fig. 9[17] shows the difference between the customary radial distribution curve and the mean distribution according to Warren and co-workers. The upper curve is given with termination at $s = 11.4$. The dashed line is a sine wave with a wavelength of 0.58 Å, and represents the error ripple. It is characteristic of this type

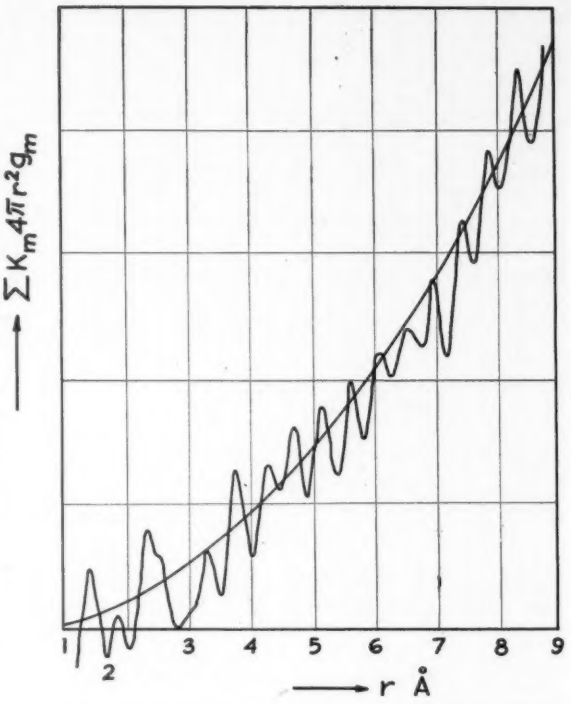

Fig. 10. Distribution curve of boron oxide glass based upon intensity measurements to s = 17.3.

of error that the radial distribution curve exhibits peaks at values of r so small in relation to the atomic diameters that the peaks can not be given any physical significance. Besides introducing false peaks, the error ripple will also effect the real areas of the peaks and render them less incorrect.

An even more striking example of how an error in an outer intensity peak gives false maxima is furnished by the recent x-ray investigation of boron oxide glass by Richter, Breitling and Herre[18]. They have measured intensities of boron oxide glass in an angular interval up to $s = 17.3$.

The resulting distribution curve (Fig. 10) consists mainly of a very strong ripple with a period of 0.45 Å corresponding to the small peak at $s = 14.0$ in their intensity curve. Richter et al did not plot the curve for values of $r < 1$ Å, and thereby avoided the occurence of false peaks due to the error period for values of r between 0 and 1 Å.

It ought to be mentioned that many of the most dominating errors may be suppressed by calculating an electronic distribution function, δ (r), using Finbank's methods[13]:

$$\delta(r) = kr \int_0^\infty I(s)\, s \sin(sr)\, ds$$

where k is a constant, and the other symbols in the integral have the same significance, as stated above.

The factor $\frac{1}{\Sigma_m f^2_m(s)}$ is avoided by Finbak, which leads to a better convergence of the integral. Hence, the error

introduced by terminating the integration at a finite limit is of less consequence. Also, errors in the intensity at outer values of s become less pronounced in the calculated δ (r)-curve. In general, subsidiary false peaks are suppressed by this procedure. In Fig. 11 is given the δ (r)-curve[19] of boron oxide glass, calculated after the intensity measurements of Warren et al, but with adjusted background. As will be seen, the false peak occurring in Warren's curve for values of $r < 1$ Å (Fig. 13), is considerably suppressed. On the other hand, the resolving power of δ (r) in r is somewhat smaller than that of Warren's distribution function.

The importance of eliminating errors in the radial distribution function is clearly demonstrated by the x-ray investigations of boron oxide glass by Richter et al, which were just referred to. Richter proposes a layer structure of boron oxide glass, which is chemically not very likely to occur. In his structure, each boron atom is surrounded by four atoms, of which three are oxygen and one is boron. The distance between the two boron atoms is somewhat greater than between the boron atom and its oxygen neighbors (Fig. 12). Richter's only experimental support of this structure is a peak at $r = 1.85$ Å, and this peak is a part of the periodic ripple plainly due to an error in the intensity curve at $s = 14.0$.

As we have seen, real peak positions along the r axis are fortunately mostly left undisturbed by the errors. The effect of errors is usually to displace the peaks upwards or downwards and add subsidiary false peaks. These errors, however, easily add up to a total error of such magnitude that the areas under the peaks should

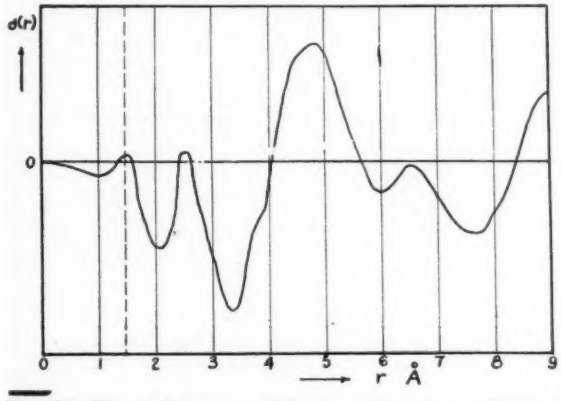

Fig. 11. The δ (r)-curve of boron oxide glass calculated from observed intensity data of Warren and co-workers.

not be given too much significance. Even if these areas were accurately known, however, the co-ordination numbers of polyatomic media as boran oxide glass could not be determined without additional assumptions.

An exact calculation of the number of electrons in the co-ordination sphere, which is necessary to determine co-ordination numbers, presupposes accurate knowledge of the electron distribution in the participating atoms. This is especially important in the case of light atoms as boron, where most of the electrons participate in bonding. As in the calculation of the background, it has also in this case usually been assumed that the atoms are in their sphere-symmetrical ground states.

If not all the atoms are equal, there is still another

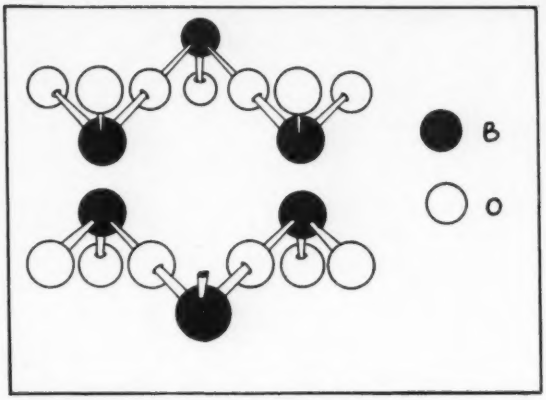

Fig. 12. The structure model of Richter of an ordered field in boron oxide glass.

Table 2

Sources of Error in Computations

(a) The measuring of the intensity with correction for polarization and absorption is not better than ± 5 per cent.
(b) The overlap of Mo- and Cu-exposures.
(c) The uncertainty in the calculation and superposition of the background curve.
(d) For polyatomic media the approximation is introduced, that the angular dependence of f(s) is the same for all types of atoms.
(e) In the calculation of the Fourier integral, the observed intensities are known only in a limited angular field.
(f) In the determination of the co-ordination numbers from the peak areas, the exact electron distribution in the atoms is not known.
(g) In the case of polyatomic media, a mean atomic number must be introduced in the calculation of co-ordination numbers from peak areas.

uncertainty, because the mean effective atomic number will have to be introduced in the calculation of the co-ordination number. This may cause an additional error.

In Table 2 is given an account of the sources of error; from this, it will be seen that the circumstances of the co-ordination number determinations are so complicated that definite error-limits hardly could be given. This will be illustrated by some examples.

Wood and Ritter[20] recently have carried out x-ray investigations of some fused salts with relatively low melting points, among others aluminum chloride. In spite of their most accurate work, the experimentally determined co-ordination numbers of aluminum chloride differ from the theoretical ones by 20 and 55 per cent for the first and the second co-ordination sphere, respectively. This disagreement is accepted as falling within the experimental error limits.

From the area of the first peak in their distribution curve, Warren et al[8] found a co-ordination number of 3.1 of boron in pure boron oxide glass. (In Fig. 13, the numbers in the peak areas are the number of effective electrons relating to the magnitude of the areas.)

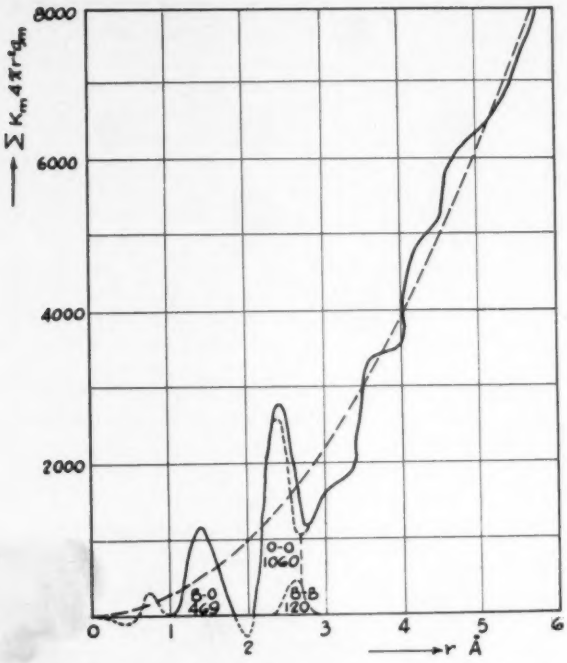

Fig. 13. The radial distribution curve $\Sigma_m K_m 4\pi r^2 g_m$ of boron oxide glass.

As we remember from the former discussion, this curve exhibits periodical error ripples, which will produce an error in the area under the real peaks. The uncertainty of the areas also is evident from the fact that the curve gives intervals of *negative* electronic density.

For sodium boron oxide glass, Warren and Biscoe[21] found that the co-ordination number of boron increases from 3.1 in the pure boron oxide glass to 3.9 when adding 33.3 mol per cent sodium oxide (Fig. 14). Warren and Biscoe suggest that this effect is real, while they assume that moderate adding of sodium oxide in the beginning will transform boron into a four-combination related to oxygen. (Theoretically they should have obtained 3.3, while only 30 per cent of the boron atoms should be four co-ordinated.)

The co-ordination number of silicon in various glasses is also determined by Warren et al[22] (Table 3). They have found values from 4.3 in pure quartz glass to 4.8 in some lime soda glasses. The disagreement with the common accepted 4 of silicon they ascribe to the experimental errors.

Sun and Silverman[23] have considered the consequence of this, and from the results of Warren's x-ray investigations they draw the conclusion that silicon can take a six-fold co-ordination in glass. The departure from a co-ordination of 4 found for silicon in sodium glass is then ascribed to a contribution of six-fold co-ordination. This, however, places emphasis in the reverse order of importance. To the contrary, the exactness of the x-ray investigations of boron glass should be doubted rather than giving importance to the disagreement from 4 of silicon in sodium glass. The co-ordination number 3 of boron has been accepted because it is considered plausible and because it is in agreement with the glass

Table 3

Co-ordination Numbers in Glass, from Warren et al

	Central element	Co-ordination Numbers Experimental	Theoretical
Pure quartz glass	Si	4.3	4
Lime soda glass	Si	4.8	4
Pure boron oxide glass	B	3.1	3
Soda borate glass (33 mol per cent Na_2O)	B	3.9	4*

*With only 30 per cent of the boron atoms in a four-co-ordination the theoretical co-ordination number should be 3.3.

theory of Zachariasen. The increasing of the co-ordination number of boron from 3 to 4, in spite of what should be expected when adding more polarizable oxygen ions from the added alkali oxide, has also been commonly accepted. The reason for this is mostly attributed to the often-occurring abnormal properties of alkali silicate glasses, as compared to the corresponding alkali silicate glasses. As appears from this discussion, however, the x-ray investigations of boron oxide glass are not sufficiently accurate to prove either the co-ordination number 3 or the assumed change in the co-ordination number when adding alkali oxide. In the case of boron oxide glass, several structure models would be compatible with the x-ray investigations when considering the limits of error. If the co-ordination number of boron is 4 in pure boron oxide glass, according to what it is in crystalline boron oxide, the experimentally-determined value of 3.1 of the glass gives about the same per cent error which was accepted by Warren in the case of silicate glasses.

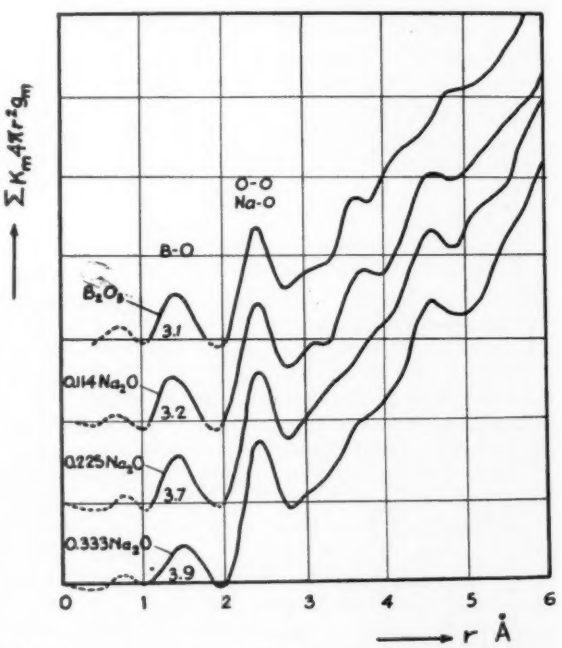

Fig. 14. The radial distribution curve of soda-boron oxide glass with respectively 0 - 11.4 - 22.5 and 33.3 mol per cent Na_2O.

IV. CONCLUSION

Thus, we may draw the conclusion that, even though x-ray investigations are the most direct way of investigating glass structures, the first x-ray investigations have nevertheless led to too far-reaching conclusions as to glass structure. With the experimental technique used up to this time, the method is by no means as useful as was formerly supposed. This fact was first emphasized by Finbak in a discussion of the x-ray scattering by liquids. Finbak proved that the method is subject to many errors. The main effect of these errors, as we have seen, is to introduce false maxima in the distribution function and to change the areas of the real peaks. But the positions of the peaks along the abscissa are not so strongly affected.

The present x-ray technique is therefore suitable in the study of atomic distances in the nearest co-ordination spheres of the atoms in glass. The method is less suitable for the determination of co-ordination numbers from the areas of the peaks. But information of the atomic distances can indirectly give evidence about the co-ordination numbers. The present x-ray technique can, however, certainly be greatly improved. Research along this line would eventually provide a more useful tool also for studying glass structures.

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TEMPERATURE RANGE OF pH SCALE EXTENDED

The National Bureau of Standards has recently extended the temperature range in which pH standards are certified. Formerly the pH scale was accurately determined only between 0° and 60°C; now standard pH samples are available from 0° to 95°C.[1] This extension was made possible by the work of V. E. Bower and R. G. Bates of the Bureau's physical chemistry laboratories.

The standard pH scale was set up to meet the need for accurate measurement of acidity and basicity in aqueous solutions.[2] In the manufacture of many commercial products—for example, paper, textiles, dyes and ceramics—the rapidity and efficiency of the processes depend upon the accuracy with which pH can be controlled. The NBS standard pH scale is defined in terms of several fixed points in much the same manner as is the International Temperature Scale. The primary standards of the pH scale are solutions whose pH values are only slightly affected by dilution or by accidental contamination with traces of acid or alkali from the walls of the container or from the atmosphere. The substances from which the standard solutions are prepared are, in turn, stable materials which may be obtained as certified standard samples from the Bureau.

In order to assign values to the NBS standards, the electromotive force of cells employing the standards as electrolytes was measured. These cells are specially designed, utilizing the highly reproducible hydrogen and silver-silver chloride electrodes. Computation of pH is based upon several reasonable assumed relationships between ionic activities and mean activities. Until recently, data for the standard potential of the silver-silver chloride electrode above 60°C were not available, so in spite of the demands of industry an extension of the pH scale to temperatures beyond 60° was not possible.

A recent determination of the standard potential of the silver-silver chloride electrode included measurements from 0° to 95°C.[3] With these new data it became possible to assign pH values over the extended range of temperatures to five of the six substances used as standards. The sixth substance recently recommended as a highly alkaline standard[4] was not certified for the extended temperature range.

(1) Standards for pH measurement from 60° to 95°C, Vincent E. Bower and Roger G. Bates, *J. Research NBS 59*, 261 (October 1957) RP 2797.

(2) Standardization of the pH scale, *NBS Tech. News Bull. 31*, 138 (December 1947).

(3) Standard potential of the silver-silver chloride electrode from 0° to 95°C and the thermodynamic properties of dilute hydrochloric acid solutions, by Roger G. Bates and Vincent E. Bower, *J. Research NBS 53*, 283 (November 1954).

(4) Calcium hydroxide as a highly alkaline pH standard, by Roger G. Bates, Vincent E. Bower, and Edgar R. Smith, *J. Research NBS 56*, 305 (June 1956).

NEW CHAIRMAN AND PRESIDENT FOR KOPP GLASS, INC.

F. S. Huot has been named president of Kopp Glass, Inc. succeeding C. J. Huot, who has been elected chairman of the board and chief executive officer of the Swissvale,

F. S. Huot

C. J. Huot

Pennsylvania producer of railroad and traffic signal lenses and industrial and technical glassware. F. S. Huot has been executive vice president since 1946 and previous to that was production manager. C. J. Huot was made executive vice president in 1937, and president in 1946.

Alexander Silverman Receives Bleininger Award

Dr. Silverman

• THE PENN-SHERATON Hotel was the scene of the eleventh Albert Victor Bleininger Memorial Award dinner, on the evening of March 14. The medal and scroll were presented to Dr. Alexander Silverman by the Pittsburgh Section of the American Ceramic Society for distinguished achievement in the field of ceramics.

Dr. Silverman, Professor Emeritus of Chemistry in the University of Pittsburgh, may well be regarded as the dean of American glass technologists because of his service to industry and education in glass, extending over more than a half century. His academic degrees include bachelor's from Pittsburgh and Cornell, M.S. and honorary Sc.D. from Pittsburgh, and Sc.D. from Alfred. He is a Fellow of several learned societies: American Ceramic Society; American Association for the Advancement of Science; Society of Glass Technology of England; American Institute of Chemists (National honorary member). Honors bestowed on Professor Silverman include the Pittsburgh Medal of the Chemical Society, election to Sigma Xi, and also election as national honorary member of the chemical fraternity Phi Lambda Upsilon and of Pi Lambda Phi. He is a member of the Pennsylvania Academy of Sciences and of other professional groups.

The major occupation of Dr. Silverman has been teaching chemistry. He served the University of Pittsburgh from 1905 to 1951, retiring after 36 years as head of the Chemistry Department. Meanwhile, he became renowned as a lecturer and consultant and was the inventor of useful glasses and illuminating devices. He directed many research projects and wrote more than 200 technical and scientific papers. Somehow, he found time to serve on committees of the International Union of Chemistry and crossed the Atlantic a half dozen times for that work.

As the program of the recent ceremonies fittingly states: "In making this presentation to Dr. Silverman, the Pittsburgh Section upholds the highest traditions of the Award honoring the memory of Albert Victor Bleininger".

Rabbi Solomon B. Freehof gave the invocation.

Following the dinner, Chairman Ralph L. Gibson of the Pittsburgh Section welcomed the guests and introduced honored guests including Charles S. Pearce, general secretary, and three former recipients of the Award—E. Ward Tillotson, Stuart M. Phelps and Francis C. Flint. Several wives were presented, including Mrs. Alexander (Elrose Reizenistein) Silverman, who was greeted with particularly warm applause.

W. Raymond Kerr took the microphone as toastmaster and read the names of the senders of a sheaf of telegrams of congratulations from friends of the awardee who were unable to be present.

Calling upon his recollections of student days at Pittsburgh, Mr. Kerr gave an intimate word picture of Professor Silverman's skill and enthusiasm as a teacher, lecturer and demonstrator. The toastmaster lived up to the best traditions of his guild.

John F. McMahon, president of the American Ceramic Society and Dean of the College of Ceramics at Alfred, spoke on "Dr. Silverman, The Ceramist". As a preface, Dr. McMahon gave an eulogy on Dr. Bleininger as a pioneer in bringing science to bear upon ceramics. That man, he said, was a leader in that group of persons who "brought note-books out of hip pockets and encouraged the scientific approach to ceramic problems". Warm and generous in personality as well as capable, Dr. Bleininger was at home in both the art and the science of ceramics. He worked, taught, translated, and wrote in such unselfish and helpful fashion as to make him one of the great figures in our profession, said the speaker, and his memory is one to be fittingly honored by annual occasions such as this.

Dr. McMahon went on to speak of the services that have been rendered by a number of outstanding chemists, physicists, mathematicians and geologists; among the names of individuals whose constructive direction is sincerely acknowledged, that of Alexander Silverman looms brightly.

The career of the awardee was briefly traced, with mention of his brilliance as a student at Pittsburgh, his work for the Macbeth-Evans Glass Company in 1902, his teaching, his continuing interest in glass, and his accomplishments as researcher, writer, and lecturer.

The Silverman Glass Collection, acquired over a period of 50 years, came in for special emphasis, because it is now the proud possession of New York State College of Ceramics. There the professor's gift is properly displayed and tended by a full-time curator.

In his brief speech of acceptance entitled "Of Books and Men", Dr. Silverman expressed his thanks in the name of former professors, associates on faculty, former graduate students, associates in chemistry and in industry at home and overseas, and in realization of the encouragement and cooperation of his wife.

Using the figures given by Sir James Jeans in "The Universe Around Us", he effectively showed that the age of man on earth especially as scientific man, is only a moment, compared with the thousands of millenia to which his residence here may extend. With such a thought in mind, a life-time is insignificant in its brevity, but it can be used, he said, to add to the sum total of knowledge for the benefit of the future.

"What I have acquired, I have learned from books and men."

In conclusion, Dr. Silverman listed his "boys" who wrote Doctors of Philosophy theses under his direction. Of these ten men, all of whom still living occupy important scientific or technical positions, Willard J. Sutton, 1924, became the first Ph.D. in America with glass as his major field. Said the Professor, "These men and their accomplishments have been my real reward."

Dean Crawford gave the benediction.

Dean McMahon emphasized Dr. Silverman's contributions to our knowledge of the chemistry and technology of glass and his awareness and grasp of the overall ceramic field. In his half century of membership, Dr. Silverman has well served the Ceramic Society and has added to its prestige at home and abroad. The speaker concluded by complimenting the committee on the selection of such a capable ceramist to receive the Bleininger Award of this year.

Dean Stanton C. Crawford of the University of Pittsburgh Faculty paid tribute to Professor Silverman as an outstanding teacher and thoroughgoing administrator, who brought renown to the University for its Department of Chemistry. He spoke of years of fruitful accomplishment and pleasant personal relations.

Fred W. Mowrey, Chairman of the Section Committee on Award, addressed the medalist with a few well-chosen words. Chairman Gibson presented the award, and the audience of 200 persons rose and ratified the act with continued applause.

MERGER OF A.W.G. AND BLUE RIDGE SANCTIONED BY COURT

On Friday, February 21, 1958. Judge Frank L. Kloeb, of the United States District Court in Toledo, Ohio, signed an order dismissing American Window Glass Company, Pittsburgh, Pa., and Blue Ridge Glass Corporation, Kingsport, Tennessee, as parties under the 1948 "Flat Glass" antitrust consent final judgment, and sanctioning the proposed merger of these companies.

The proposed merger of the two companies would result in a new company expected to be known as American-Saint Gobain.

Attorney General William P. Rodgers sanctioned the proposed merger of these two companies for the asserted purpose of setting up new competition in the flat glass manufacturing field.

American Window Glass Company, which was formed in 1899, is an important producer of quality sheet glass products with national distribution through independent jobbers. In 1957, American accounted for an estimated 18 per cent of domestic sheet glass production. The company operates sheet glass plants in Arnold and Jeannette, Pa., and serves the West Coast and Southwest from its newest plant in Okmulgee, Okla. Laminated safety glass is produced by its wholly owned subsidiary, Glass Products, Inc., at Ellwood City, Pa., and modern research facilities are maintained at Monroeville, Pa.

Blue Ridge Glass Corporation, a wholly owned subsidiary of Saint-Gobain of Paris, France, produces rolled, figured and wire glass, spandrel glass, tempered doors and special glass for the lighting fixture trade.

American Window Glass Company expects to submit a proposed plan of merger to its stockholders at an early date.

One objective of the merger will be for the newly formed company, American-Saint Gobain, to build a new plate glass manufacturing plant in the United States which will embody the latest manufacturing methods used by Saint-Gobain, including twin grinding and twin polishing. Preliminary engineering for the proposed new plate glass plant is well advanced and exhaustive surveys have been made of suitable plant sites. Construction of the plate glass plant, however, must await arrangements for financing by the successor company, American-Saint Gobain.

The addition of the proposed plate glass plant will give the new company production facilities for a full line of flat glass products, including plate, window, rolled, figured and wire glass, and safety glass.

The court action clears way for the merger of American Window Glass and Blue Ridge Glass inasmuch as the consent judgment prohibited mergers in this field without court approval. The order becomes effective upon completion of the merger. A stipulation was filed with the order under which American and Blue Ridge agreed to abide by selected provisions similar to those in the consent judgment.

Assistant Attorney General, Victor R. Hansen, head of the Antitrust Division, said in a statement:

"Based upon a thorough study of this particular situation, the Division concluded that the judgment's purpose would be best fulfilled here by permitting the creation of a new company with a modern glass plant, which would result in an effective integrated competitor in this field. Independent jobbers and direct buyers should benefit from the new source of supply which the proposed company can be expected to provide."

F. G. PASOTTI, OF LYNCH, DIES

F. George Pasotti, well known glass engineer, died Sunday, March 9 at the age of 61. Embolism was said to be the cause of death.

Mr. Pasotti, who was formerly associated with the U.G.B. in England, came to this country in the early 1930's. He was an expert in glass machinery and spent his entire life working in that field. During his association with Ball Brothers Company, Muncie, Indiana, he was in charge of their machine shop. After that he worked for the John Eldred Company, Columbus, Ohio.

At the time of his death, Mr. Pasotti was employed by the Lynch Corporation, Anderson, Indiana. He is survived by his wife and two sons.

Glass: Its Transparency and Structure

Part III. Transparency and Structure of Liquids and Glasses

By H. H. HOLSCHER, Technical Assistant
to Director of Research, Owens-Illinois Glass Company, Toledo, Ohio

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Summary of Structure of Glass

11. Why is Glass Transparent?

9. TRANSPARENCY OF LIQUIDS

(Reference 30) We can look upon gases as having no definite shape and volume, upon liquids as having definite volume but no definite shape, and upon solids as having both a definite shape and a definite volume. Thus the liquid shape is controlled by the vessel. The liquid surface results when the liquid completely fills the vessel up to a level under the influence of gravity. The liquid shape is controlled by the vessel shape. We can look upon gases and liquids as having no rigidity and because of this they take the shape of their containers. Solids, in contrast, possess definite rigidity.

In the simplest fashion we can compare the types of atomic, molecular or particle motions which are common to the three states of matter as follows:

State	Motion	Action Between Atoms
Gaseous	Totally free	Very little
Liquid	Diffusion or translation; attraction or cohesion; rotation; vibration	Attraction and repulsion
Solid	Vibration; rotation	Motions only possible about a "fixed mean position" in the space lattice

A liquid may be looked upon as a condensed gas or as a melted solid. Both views have their respective effects upon our picture of the structure of liquids. The theory of liquids is in a much less satisfactory state than the theories of gases and crystals. On this basis the transparency or nontransparency property of liquids is also not well explained.

Many simple liquids are transparent and many are colored. The presence or absence of coloring ions or of particles which give light scattering are primary factors in the discussion. However, the absence of internal surface effects within a homogeneous liquid must be explained.

9.1. Structure of the Liquid State

(References 5, 8 and 9) As stated above, this field is one of much conjecture. The biggest difficulty in a consideration of the liquid state is to explain the mobility of the liquid. We mentioned that liquids have no

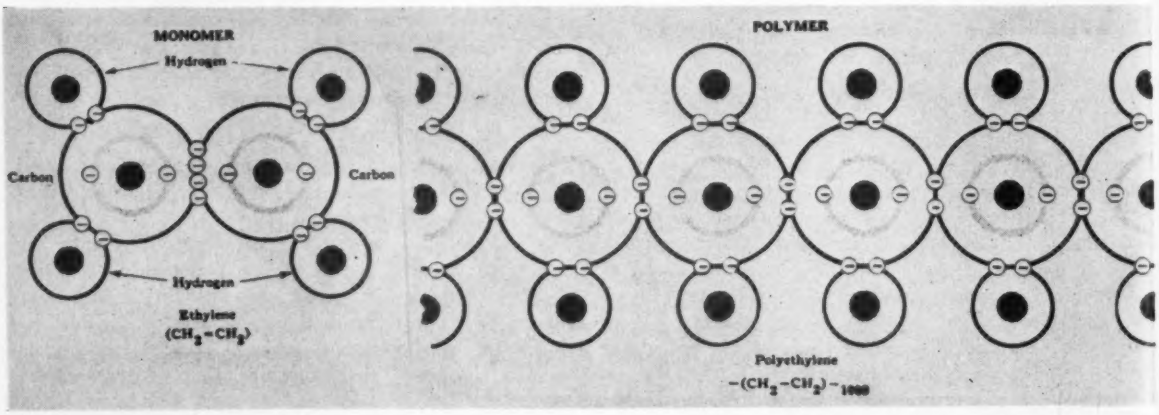


Fig. 20. Plastic monomer and polymer. Polymers are substances in which a chemical structure unit occurs repeatedly. Here the polymer polyethylene results from repetitive additions of the monomer ethylene. (Ref. 23) From "Fundamentals of Electrical Insulators", J. Swiss and T. W. Dakin. *Westinghouse Engineer, 14* (1954).

rigidity. In explanation of the mobility, it is necessary to assume that flow occurs as a result of simultaneous displacements of whole groups of molecules. X-ray diffraction studies of simple liquids have shown that there is a more or less orderly arrangement of molecules in simple groups as if the liquid were attempting to assume the orderly structure found in crystalline solids. However, the X-ray pictures show only a very short range order—that is, generally limited to the molecular dimensions in the first nearest neighbors. The patterns show in general that the structure which could be expected for the second nearest neighbors has almost vanished, and instead there is evident a continual diffuse picture which shows that a liquid has many second neighbors in the dimensions of range to be expected in a crystal from first to second neighbors.

"The diffraction of X rays by water has been thoroughly studied, and indicates that some of the peculiar open packing in ordinary ice remains. In ice, each oxygen atom is surrounded by four other oxygens, arranged tetrahedrally at a distance of 2.76 Å. In water, four oxygens are located around each oxygen atom at an average distance only slightly greater than this, about 2.9 Å. The next nearest neighbors are found, in ice, where the tetrahedral structure is maintained throughout the crystal, at a distance of 4.5 Å. (there are twelve of them). In water, at room temperatures, the definiteness of this second shell has almost vanished; the X-ray results indicate a slightly greater concentration of oxygen atoms with their centres 4.5 Å from a given atom, than at rather smaller or greater distances; but the ice-like structure has been so much broken down that many molecules are found at distances between 4.5 Å and 2.76 Å, having broken into the space between the first and second shells which is vacant in the crystal. As the temperature rises to near 100° C., the first shell with roughly 4 molecules expands somewhat (to about 3.05 Å for the maximum concentration), and the traces of a second shell at 4.5 Å practically vanish." (Reference 9)

Thus we get the general picture that the structure of the liquid state in the realm of the first atomic dimensions is very close to that of the crystal, but that, beginning after this nearest neighbor, there is a diffusion and a collection of atoms at different distances, none of which are related. This means that the grouping of such units which gives structure must be looked upon as continually adjusting and changing. The grouping must be such that its realm of size must be outside those which are visible and that any surface effects must be so short-lived as to be unimportant. Similarly, there must be immediate and complete readjustment of the grouping to the new space and the environment. Two facts are therefore essential: (Reference 8)

> "First, there may be local irregularities caused by groups of molecules coming close together, leaving wider spaces elsewhere in the structure.
>
> "Second, there may be gradual distortion of the structure as we go from molecule to molecule, so that although the pattern in the immediate neighborhood of a given molecule may be quite regular, the pattern is irregular at a distance."

This "order-disorder-order" picture, which for the same molecules an instant later may be better classified as "disorder-order-disorder" (that is, it is always changing due to mobility), implies an interchange between volumes of great order, but this interchange grouping is itself capable of great order, The continual connecting and disconnecting with other similar units avoids the presence of any boundary areas. Permanent surfaces similar to those in a solid crystal are never evident. Thus the structure fails to have areas which give wave bending or reflection. The molecular structure units may be looked upon as ordered like a crystal, with the fine structure containing some molecular order, but surrounded continually by changing order. The gross structure does not produce boundaries which are characteristic of crystalline solids. The high mobility gives continual changing of neighbors.

If there are surface-like discontinuities which would normally give reflection, they are bordered (due to liquid mobility) with another such surface-like discontinuity and these discontinuities are so intimate that index of refraction changes do not exist. Light bending and reflection are avoided by this great facility to adjust shape. Intimacy between any disordered volumes must be close to molecular. Mobility contributes to this intimacy.

Just one statement should be made here in relation to glasses and this view of liquid structure. In glasses at a high temperature we start out with a true liquid. We freeze the structure when mobility becomes lower. As Weyl says, "The chief difference between the structure of a liquid and of a glass consists in the fact that in liquids the neighbors of each are constantly changing, whereas in a glass each atom finds itself surrounded by a number of other atoms at approximately defined distances." (Reference 5)

9.2. Presence of Ions in Solutions

There are many effects which occur when a salt such as NaCl is placed in water. We have, of course, the predominant one, which involves the formation of ions of sodium and chlorine in the solution and the fact that these ions are no longer rigidly bound as they are in the solid crystalline NaCl. Because of this we get ionic conductivity or conductivity due to the actual motion of the ions progressing to their respective positive or negative electrical poles and being deposited as molecules at these poles, with change of the electrons and the subsequent ability to carry electricity. This type of conductivity, known as ionic conductivity, actually involves, as we stated above, a movement of ions. It is different from electronic conductivity, which involves movement only of electrons. In the case of dilute solutions, these ions are so far apart that they generally have no electrical effects on waves which pass through the solution. This view implies distances which are similar to those in gases.

Now when we progress to the situation of concentrated solutions, we are still more baffled from the standpoint of theory. In fact, glass at high temperature can from one standpoint be considered as a concentrated solution of oxide within oxide or of mutual solution in each other. Glass does have ionic conductivity when it is fluid enough to allow the flow of ions, and, in fact, the electrical conductivity of glass is more or less controlled by the movement of the ions in the structure. How-

Table 4

Molecule Size vs. Properties*

Moving Element	Average Vol. Å³	Viscosity at Melting Point, Poises	Relaxation Time in Seconds	Typical Examples
Single Atom	10	10^{-3}	10^{-13}	Argon Gas
Weak Single Molecule	50	10^{-2}	10^{-12}	Pentane
Strong Single Molecule	500	1-10	10^{-9}	Alcohol
Aggregates of Molecules	10^{2}— 10^{4}	10 — 10^{2}	10^{-8}	Glycerol
Segments of Molecules	10^{2}— 10^{4}	10^{3}— 10^{5}	10^{-6}	Vinyl Polymers
Aggregates of Macro molecules	10^{5}— 10^{8}	$>10^{5}$	$>10^{-5}$	Cellulose Esters

*Adapted from Reference 6.

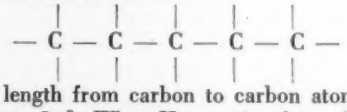
ever, as long as these ions exist in a liquid type structure, the neutralization or interaction with light waves can only occur by the movements of ions (not just electrons). This involves a considerable mass movement. Furthermore, the charges of the ions are not easily removed unless the energy becomes fairly great and unless it is absorbed. Also, the ions present are both positive and negative.

9.3. Viscous Liquids and Liquids with Large Molecules

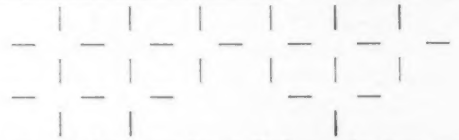
(References 6, 23 and 30) In Section 7 we concluded that when particles approached 4000 Å we could study their details and that we got light spots from particles of somewhat smaller dimensions due to the scattering effect.

There is an intermediate range of molecular dimension which covers the field from simple molecules to complex molecules and to polymers. (See later.)

Many of the properties of relatively viscous liquids are more or less directly related to the molecular dimensions involved. We hear the term "polymer" applied to plastics and to glass, and we mean the building up from single units which are called "mers" of molecular structure into a grouping which contains many (poly) such units. Thus a polymer is a substance in which a chemical structural unit occurs repeatedly. A monomer is the simplest unit from which a polymer can be formed. See Fig. 20. Plastics include cases where there are only a few, say ten, such units to the molecule up to instances where there are thousands or even hundreds of thousands to the molecule. One fundamental building unit of the plastics is the carbon chain:



where the length from carbon to carbon atom is in the realm of 1 to 2 Å. When H occupies the ends of bonds shown, we pass from gases (1 to 4 carbon units) to liquids (5 to 20 carbon units) and then to solids (more than 20 carbon units). The latter solids are waxes. Longer chains give higher softening temperature, decreased solubility, and increased strength. (Reference 6) In many cases such large molecules have cross linkages which involve not only building in the direction of increased length of the chain, but in the cross connection of chains together. For instance:



This cross linkage results in higher softening temperature. Thus we can arrive at the fact that many plastics molecules have dimensions in the realm from 10 up to 1000 Å, and in many cases much larger. These large molecules tend to give the plastic material increased viscosity. They also result in an increase of time required for stresses to release themselves when the viscous mass is placed under strain. This time is known as relaxation time.

a. Relation of Size of Molecule to Viscosity and Relaxation

Broad relationships between molecular weight, viscosity at melting point, and relaxation time for a group of different sized molecules are given in Table 4.

These are not universal relationships and broad interpretations are certainly not warranted.

It is to be noted that the average volume as specified for the *largest units* given in Table 4 amounts to a dimension of from 50 Å to nearly 1000 Å on a side if the structure is considered of cubic nature. This general range of particles does not show up as light scattering. They do produce Rayleigh scattering. (See Table 3.)

b. Plastic Properties vs. Structure

(Reference 23) It is well to relate properties and structure by using plastics as an illustration.

> "If the forces of attraction between the molecular chains are small and the chains do not form readily into a regular geometric pattern, or lattice, the normal thermal motion of the atoms tends to cause the chains to assume a random, more or less coiled arrangement. These conditions lead to a rubber-like character. If the forces between chains are strong and the chains fit easily into a regular geometric pattern, the material is a typical fiber. In intermediate cases, where the forces are moderate and the tendency to form a lattice is also moderate, the result is a typical plastic.
>
> "In general, the tendency to crystallize is determined by two opposing factors: (1) the forces between the molecular chains, and (2) the geo-

metrical bulkiness of the chains. The forces between chains are determined by the nature of the groups in the polymer. Purely hydrocarbon groups (CH_2) have the lowest molecular cohesion, whereas amide groups (C, H, O, N compounds) have the highest. In a general sense, this is because the amide groups have more outer-shell electrons available for interaction than do the hydrocarbons. Halogens (Cl, Br, I), ester groups, and hydroxyl groups lie in between.

"The manner in which elements are joined in such chains—as well as the choice of elements—has a decided effect on resultant properties. For example, two polymers with the same constituents, and in the same quantity, such as polyisobutylene and polyethylene, may vary considerably in their form and characteristics. In the case of these two compounds, polyethylene (Fig. 20) has all its carbon atoms joined together in a straight chain; polyisobutylene, on the other hand, has methyl groups (CH_3) attached to alternate carbon atoms. These methyl groups have the effect of spreading the chains apart and making polyisobutylene at comparable molecular weight a viscous, tacky liquid rather than a solid. Because of its tackiness and its nonpolar character, polyisobutylene is used as a low-loss bond for flexible mica products.

"Some high polymers are used as three different materials—rubber, plastic, fiber. Polyethylene, for example, is used as a substitute for natural rubber in wire covering, as a plastic in housewares such as tumblers, refrigerator containers and food-packaging bags, and as a fiber in acid-resistant filter cloths, where high fiber strength is not required.

"The one polyester, derived from terephthalic acid and ethylene glycol, is the fiber Dacron and the plastic Mylar. To make the fiber, the filament extruded from the polymer melt is 'oriented' by rewinding it from one spool to another, rotating at five times the speed of the first. This stretches the filament 400 percent, drawing the chains of molecules closer together, and causing crystallization in the direction of the fiber axis. This increases the flexibility and tensile strength of the fiber markedly. Synthetic fibers are thermoplastic, albeit high melting; this is necessary to permit orientation.

"To form the plastic Mylar, the extruded melt is oriented by stretching in two directions. The orientation is not nearly as complete as is the case with the fiber, and a material with the properties of a plastic results. The lack of complete orientation in such films results in a tendency for recrystallization to occur in a random manner at elevated temperature (above 150°C.), with resulting embrittlement; life is often limited by physical change rather than chemical deterioration."

It is interesting to note that plastic materials can be made opaque by the addition of fillers which are fine granular solids inserted therein, or plastic materials can be made partially or totally opaque due to their becoming polycrystalline. The ordinary squeeze bottle, which is polyethylene, is only partially transparent because it is partially crystalline in nature. It is a good example of a material becoming opaque by crystallization.

c. Silicate Glasses

We shall discuss later (see Section 10) the present ideas on the structure of glass. We do wish to point out here some of the changes of glass viscosity which occur during the melting and fabrication process. This is purely to relate it to Table 4. Glass is considered a liquid at its melting temperature and has a viscosity of 10^2 poises. As the temperature is reduced it becomes viscous enough to be fabricated by blowing, and this fabrication range varies from about 10^3 poises down to about 10^8 poises. From here on down it becomes more and more viscous and we define viscosity down to a realm of about 10^{15} poises. It is interesting to compare these viscosity ranges with the viscosities given in Table 4. Actually, you see, we are progressing through a different range of viscosity than Table 4; but *at the melting temperature*, if we were to make direct comparison, we would note that 10^2 poises refers to a molecule having about 10^4 cubic Å in volume. A grouping with this volume, assuming it were cubical, would have a linear side dimension of about 22 Å. This gives a probable idea of the size of the molecule, but *this is only indirect evidence based on a very simple concept.* However, considerable recent experimental work on the structure of glass seems to indicate that the macromolecule in the glass structure is certainly in this realm of dimension.[1]

Up to this point we have supplemented our picture of transparency with a view on the structure of liquids and with some consideration of the effects which take place when we have liquids of increasing viscosity. It has been stated that liquids may have units of structure varying from simple molecular dimensions up to many times molecular dimensions and that the great mobility does not permit the development of surfaces or other in-between types of separations between units. A lower order of structure exists as we approach the periphery of the units, and this structure diffuses from one unit into the adjacent unit to an extent that surface does not develop, or if it does develop, it is so short-lived as to be ineffective in its influence on light.

Transparency of Some Liquids

Transparency involves a picture of structure in which internal surfaces, of such dimension and of such properties as to reflect or refract light waves, do not develop. This concept is a direct relation to the structure of liquids. Glass, on cooling down from a liquid at high temperature, does not normally develop such internal surfaces. If it does, we get nontransparency (for instance, crystallization).

10. WHAT IS A GLASS?

10.1. Definition of a Glass

(Based largely on References 33, 42 and 43) As a general introduction to the subject of glass, we must state that there is no single satisfactory definition of glass. There are those who separate glass and the glassy state, and in the latter term include a lot of trans-

[1] One cannot interpret viscosity *below* the melting temperature in this fashion. This is strictly limited to a comparison at the melting temperature and is then only broadly interpreted.

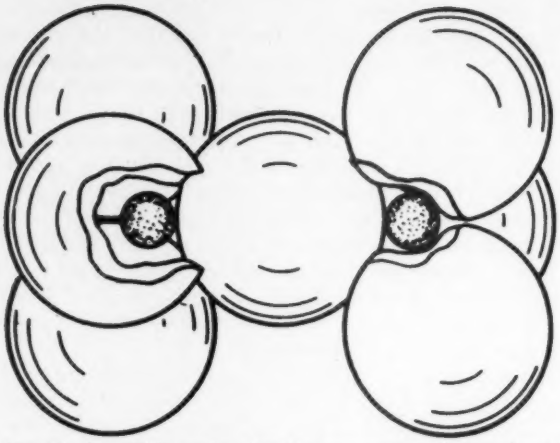


Fig. 21. Two SiO_4 units showing one oxygen being shared by the two. (Ref. 10)

parent materials which have some of the properties characteristic of glass, but do not have its temperature resistance and permanency. We are referring, of course, to transparent plastics.

Historically, it is perhaps difficult to determine the first term used to describe the nature of glass. Because glass did not show any consistent shape or form under the highest magnification, it was often called "amorphous." This term means irregular or lacking shape. The terms "vitreous" and "vitreous state" were and still are useful and descriptive. They do not, however, define the basic atomic nature of the structure, but merely mean "glass-like." Implications are often made on the type of fractured surface, brittleness, deformation under heat, etc.

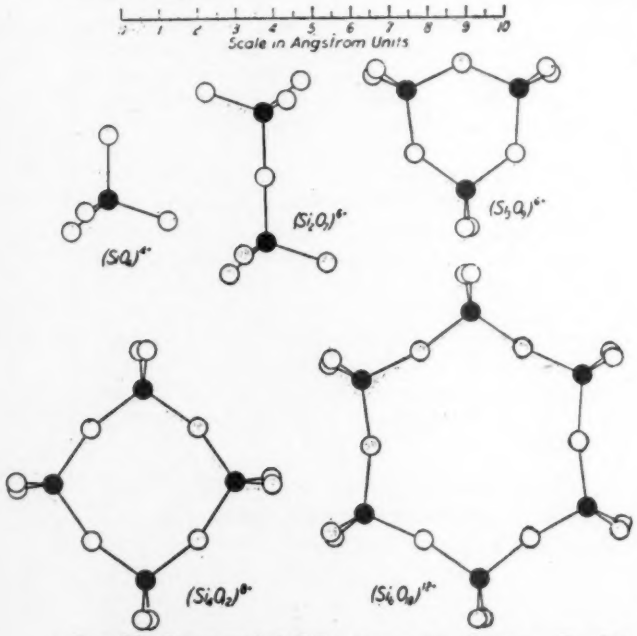


Fig. 22. Compounded SiO_4 groups in silicates. In this figure the oxygen atoms are not shown to relative size of the silicon atoms. See Fig. 9, where they are shown in the correct relative size. This figure shows 1, 2, 3, 4, and 6 silicons in different bonding arrangements. Compare the Si_2O_7 diagram with Fig. 21. (Ref. 12)

Another term often used is "isotropic," which means possession of the same properties in all directions. For a transparent body, reference is usually made to isotropic optical properties.

Certainly an early idea of the structure of glass was based on the usage of the term "supercooled liquid." In connection with this latter usage, one often refers to molten glass as a "solution" of one oxide within another oxide, or rather a mutual solution of constituents within each other. The molten liquid is cooled without crystallization to form a rigid body at room temperature.

In recent years the theory of the atomic structure of glass advanced by Zachariasen (Reference 44) has become widely accepted. This "random network" theory assumes unit building blocks placed together in a random network manner (which avoids any periodicity, repetition or symmetry characteristics of crystals) to allow complete satisfaction of electrical and valence requirements. This would lead to a viewpoint of rather large units of structure (the term "unit cell" cannot precisely apply here), plus the situation that no two units may be precisely alike (see Section 10.3). The determination of the nature and size of these larger units of structure is one aspect of present fundamental work in this field.

The actual engineering definition of a glass does not necessarily refer to any of these statements because the engineer is not particularly interested in the structural setup. He generally refers to glass as an inorganic product of fusion which has cooled to a rigid condition without crystallizing. He then goes on to consider the glass as hard and brittle, colorless or colored, transparent or opaque. He may also define specific kinds of glasses on the basis of some of the constituents that are used. (These are in the ASTM definition.)

Three definitions seem to be necessary in order to give the broad realm of the field:

a. The American Society for Testing Materials' Definition

(Reference 42) "Glass is an inorganic product of fusion which has cooled to a rigid condition without crystallizing."

"(1) Glass is typically hard and brittle, and has a conchoidal fracture. It may be colorless or colored, and transparent to opaque. Masses or bodies of glass may be made colored, translucent, or opaque by the presence of dissolved, amorphous, or crystalline material.

"(2) When a specific kind of glass is indicated, such descriptive terms as flint glass, barium glass, and window glass should be used as understood by trade custom.

"(3) Objects made of glass are loosely and popularly referred to as glass; such as glass for a tumbler, a barometer, a window, a magnifier, or a mirror."

b. The definition for glass given by Morey in his book, "Properties of Glass"

(Reference 33) "A glass is an inorganic substance in a condition which is continuous with, and analogous to, the liquid state of that substance, but which, as the result of a reversible change in viscosity during cooling, has attained so high a degree of viscosity as to be for all

practical purposes rigid."

c. A definition of vitreous state given by Huggins, Sun and Silverman, as follows:

(Reference 43) The vitreous state is defined as "that state in which the arrangement of the component atoms, ions, or molecules possesses a permanence similar to that in the crystalline state and a randomness similar to that characteristic of liquids."

10.2. Continuity of Properties vs. Temperature

We have mentioned that undoubtedly one can consider glass at high temperatures, where it has a viscosity of 100 poises, as a liquid. However, as we lower the temperature there is always some tendency for glass to form crystals. There is a type of crystal which is characteristic for each particular composition. However, when we cool glass we cool it so rapidly that crystallization cannot develop. In other words, the viscosity becomes too great to allow the ions to migrate into the positions called for by a crystal. Thus one of the first concepts is that glass is in a metastable form at room temperature. Its great rigidity maintains this instability for great lengths of time (perhaps hundreds of years or indefinitely).

The second important point about glass is that the viscosity change to a highly viscous material progresses continually as we reduce the temperature. It is this viscosity change which largely controls a great many of the properties. In fact, down to some specific range of temperature we consider that glass adjusts itself (relaxation) within a very short time. However, when we get into some lower range of temperature, we find that the adjustment, or relaxation we have previously referred to, takes much time. In the intermediate temperature range the time factors may be only a few seconds, but as we come on down in temperature it may be practically impossible to allow complete adjustment because of the time required. Obviously, then, the glass tends to readjust itself to a more stable condition, but this adjustment is slowed or even arrested by greater viscosity.

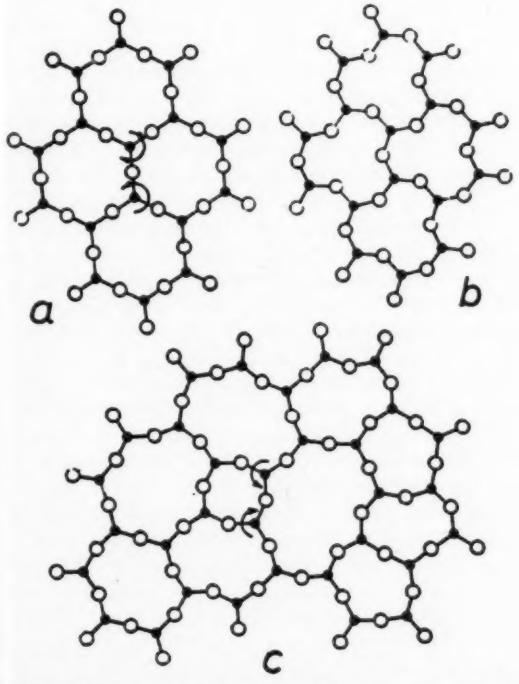


Fig. 23. Crystalline structure for SiO_2 is shown in a and b. The vitreous structure is shown in c. Here the random network illustrates linkages of 4 and 8 tetrahedral units. (Ref. 10)

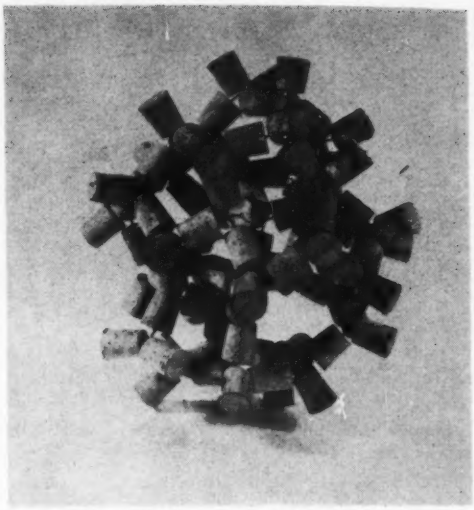


Fig. 24. A three-dimensional model of the network of fused silica with four bridging oxygens per one tetrahedron. The bridging oxygens are shown as white corks, while the soldering points of the wires represent silicon atoms. (Ref. 14.)

The range in temperature where this time factor becomes measurable is the range which has often been referred to as transformation. Actually the transformation really covers a temperature range where the time factors become noticeable in the normal realm of experimentation. Thus we should not state that glass suddenly transfers from a viscous to a brittle material, but we should rather state that everything having to do with glass is related to a rate process. On this basis the properties must be considered continuous down to room temperature, even though breaks may be evident due to insufficient time. In other words, there is just a radical increase in time required for equilibrium and soon we reach a state where time is so great that we never hope to reach stabilization. In effect, we freeze into the glass a condition which represents some higher temperature.

Glass at room temperature is a rigid solid possessing elastic and other characteristics of solid materials. At high temperature, when glass is molten, it is a liquid and possesses the characteristic properties of liquids, such as true viscosity, etc. In an intermediate temperature range, referred to in the paragraph immediately above, glass possesses the characteristics of both a liquid and a rigid solid. Viscous flow, which is characteristic of liquids, and elasticity, which is characteristic of solids, can both be measured. This intermediate range is therefore often referred to as the viscoelastic range of glass.

10.3. The Structure of Glass

It is essential, before entering into the structure of glass, that we should have some idea as to the structure

of crystals made from the main constituents which compose glasses. The major components in silicate glasses are, of course, oxygen and silicon.

a. The Crystalline SiO_4 Network

(Based largely on References 10 and 12) Oxygen has a very large atomic radius and silicon a rather small atomic radius (see Fig .8). From the standpoint of structural building of the units, the commonly accepted picture is one involving SiO_4, in which four oxygens are arranged around a small silicon in a tetrahedral fashion. The oxygens are so large that they can contact each other and still have sufficient space within the center to accommodate the silicon. Fig. 9 gives a view of this tetrahedral formation expanded on the left for visibility and to scale on the right. In the crystal form SiO_2 each of these corners representing the oxygen atoms is attached to a second silicon atom, and so each oxygen must be considered as sharing itself with adjacent silicons. Fig. 21 represents the simplest case of two SiO_4 units adjacent, but where the oxygen between the two is shared by the two silicon units. This is listed as an Si_2O_7 unit. Because the SiO_4 units in the crystal share all of their oxygens, we can consider that we come back to the basic fundamental relationship of the SiO_2 as the chemical composition of the mass and retain electrical neutrality. This SiO_4 tetrahedron is the basic foundation for many crystalline silicates when taken together with multiple groups, such as Si_2O_7, Si_3O_9, Si_4O_{11}, Si_4O_{12}, Si_6O_{18}, etc.

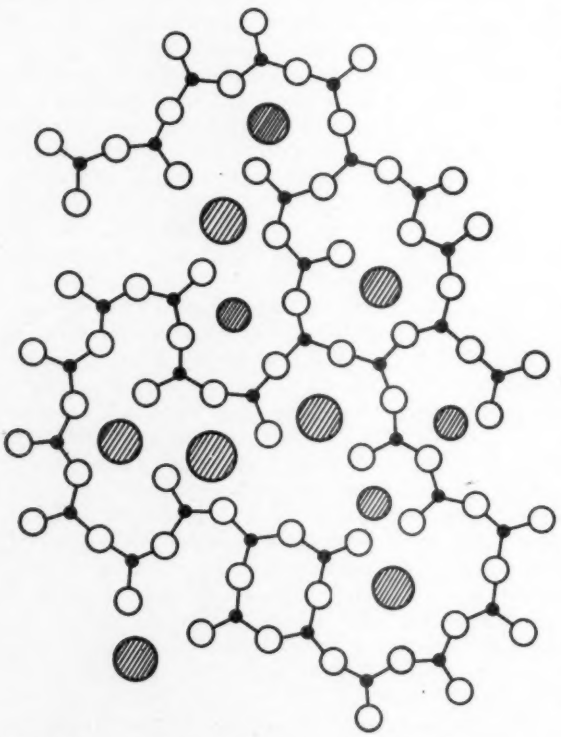


Fig. 25. A two-dimensional representation of the structure of glass according to Zachariasen. The network so formed consists of network-forming atoms (represented as small black dots), bridging and nonbridging oxygen atoms (represented by open circles), and network-modifying atoms (represented by shaded circles). (Ref. 14)

(See Fig. 22 and Reference 10.) These can represent chains, double chains, sheets, rings, etc. The SiO_4 tetrahedron is also the basic fundamental packing unit which represents the realm of short order which acts as a center of high order for structure of liquid silicates. Therefore, it must be considered a center around which we have the other distortions and second nearest neighbors which involve the structure concerned for liquid glass.

We cannot represent the SiO_4 tetrahedron on a flat sheet of paper. The best representation that can be given is that shown in Fig. 23, which in portions "a" and "b" shows structures for crystalline silica.

b. The Vitreous SiO_4 Network

(References 10, 14, 44 and 45) The most simple glass that may be considered is vitreous silica or vitreous SiO_2. In this and in all of the silicate glasses the silicon ion maintains its tetrahedral co-ordination (co-ordination number, a frequently heard term, indicates the 4-to-1 ration of atoms—Fig. 9). The primary difference between a crystal and a glass lies in the manner in which these tetrahedra are linked. In the crystal the structure repeats itself continuously in three dimensions, while in vitreous silica the tetrahedra are linked in a random network so that no such orderly repetition occurs. An illustration of this random network is shown in Fig. 23-c. This theory was first theoretically proposed by Zachariasen and was given experimental consideration by X-ray methods by Warren. It is unlikely that we can assign, therefore, any type of a unit cell (see above under Section 4) because the random nature would prevent exact repetition. It is noted in Fig. 23-c that some of the SiO_4 tetrahedra are linked together in units representing four such linkages and in other units representing five, six, seven, etc. The larger these chains become, the more open the network.

It is perhaps easier to visualize such a random network by a look at Fig. 24, which is a picture of a three-dimensional model of a network of fused silica. The model was made from ordinary corks and copper wire, with the soldering points representing silicon atoms and the light-colored corks representing bridging[1] oxygen atoms. (In this figure all of the corks are light because all the oxygens are bridging oxygens (they each connect to two silicons). In some future figures—for instance, Figs. 27 to 29, etc.—we shall use some dark-colored corks which represent nonbridging oxygen atoms. These we shall explan more fully later.) A study of Fig. 24 shows that there are holes of different sizes in the structure. There is no repetition which could be considered crystalline, yet we have completely satisfied all valences and have an electrically balanced SiO_4 network which is represented by the chemical formula SiO_2.

In this network it is common to speak of the SiO_4 units as being glass formers. A glass former could be defined as that unit present which determines the overall structure of the network. Sometimes there is more than one such glass former in a glass.

c. Soda-Silica Glasses

(Reference 14) The above structure as given for vitreous silica carries through as the predominating influence

[1] Bridging means that the oxygen atom bridges or connects two silicon atoms.

in all types of silicate glasses. There are, however, other basic glass-forming units, but we cannot consider them in this brief discussion[1]. We add other materials to vitreous silica to form commercial soda-silica and soda-lime-silica glasses. These materials are most often referred to as network modifiers—that is, they tend to modify the SiO_4 network and to open it up because *they introduce into the network a larger number of oxygens than can be contained in a structure where all oxygens are bridging between two silicons.* This opening up of network therefore produces some so-called non-bridging oxygens which are connected to only one silicon and cause a break in the structure. Such a structure is represented in Fig. 25 for a soda-silica glass in which the soda ions are considered to lie within the holes of the SiO_4 network. Their valences are satisfied by free valences left over when an oxygen atom is nonbridging. The networks are more opened up, however, and have some *free ends of oxygen* which are nonbridging. It might be easier to visualize this type of structure if you referred to Fig. 26 in which each of the triangles represents the individual tetrahedral structures (reduced to flat paper). In this picture silicon atoms are represented by black dots and the network modifiers by gray circles. Bridging oxygen atoms are represented by white circles[2] and nonbridging oxygen atoms by white circles with the dot. This gives again some idea of the various types of holes which occur and shows how they can accommodate different sizes of atoms which go to make up glass (Fig. 8).

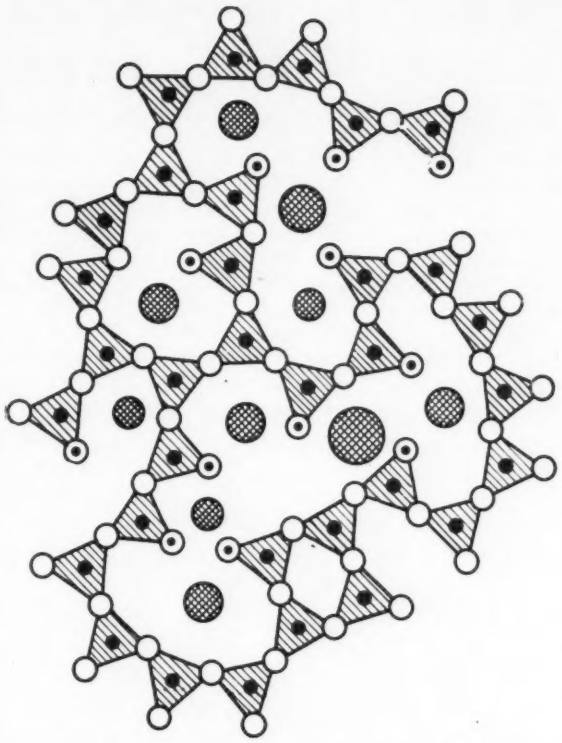


Fig. 26 The well-known schematic, two-dimensional representation of a silicate glass according to Zachariasen. Silicon atoms are represented by black dots, the network modifiers by gray circles, bridging oxygen atoms by white circles, and nonbridging oxygen atoms by white circles with dot. The shaded triangles represent SiO_4 tetrahedra. (Ref. 14)

d. More Complex Glasses[1]

(References 14 and 20) We have mentioned above that the introduction of sodium oxide brings in extra oxygens which must be accomodated in the network and leaves the sodium as an ion being held in holes. It seems desirable here to further enlarge upon the fact that the ratio of oxygens to silicons changes greatly in the network, but the network still accommodates them. We will call this R, which we define as: (Reference 14)

R = Ratio of Oxygen Atoms to Silicon Atoms

We are most interested in the relationship of nonbridging oxygen atoms (bridging means that the oxygen atom bridges or connects two silicon atoms) to the structure of the network. We will define two more algebraic terms, as follows:

X = Average number of nonbridging oxygen atoms per tetrahedron.

Y = Average number of bridging oxygen atoms per tetrahedron (or average number of points of contact per tetrahedron)

To maintain tetrahedral co-ordination (which has been described—Section 10.3a—as a requirement of the structure picture) we must maintain

$$X + Y = 4$$

The tabulation given later shows the relationships[3] of R, X, and Y for a series of vitreous compositions.

The structure becomes more and more open as the number of bridging ions per tetrahedron decreases—that is, as Y decreases. We show in a series of figures the progression of structure as Y goes from that of vitreous silica or 4 down to a Y value of 2.2, as follows:

Fig. 24: $Y = 4$
Fig. 27: $Y = 3$
Fig. 28: $Y = 2.6$
Fig. 29: $Y = 2.2$

(It is interesting to derive what happens when $Y = 2.0$.)

In Figs. 24, 27, 28 and 29, the black corks represent nonbridging oxygens. The ratio of black corks to white corks gives some idea as to the openness of the network. This type of gradation of the openness of the SiO_4 structure can be represented also on flat paper by Figs. 30, 31, and 32. These figures 24, and 27 to 32 make no

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[1] The complex chemical nature and composition of glasses are evident from A. Winter (Ref. 56), who relates glass-forming constituents to the periodic groups in a broad fashion.

[2] Remember, the structure proceeds on outward from the shown diagram, so outer white circles bridge to atoms not shown.

[3] Some algebra is involved in these tabulations. First $X + Y = 4$ to hold tetrahedral co-ordination. By definition,

$$R = X + \tfrac{1}{2} Y$$

because each bridging oxygen (each Y) connects to two tetrahedra and therefore only ½ Y is used per one tetrahedron. But each nonbridging oxygen (each X) attaches to only one tetrahedron. So per unit tetrahedron, the total oxygens combine to produce a ratio of oxygen atoms to silicon atoms as follows:

By definition

$$R = \frac{\text{Number oxygen atoms}}{\text{Number silicon atoms}}$$

But per one tetrahedron, the denominator is unity, so

Therefore R = Number of oxygen atoms per tetrahedron

Therefore $R = X + \tfrac{1}{2} Y$

or $2R = 2X + Y$

$Y = 2R - 2X$

If X = 4-5, then

$Y = 2R - 2(4 - Y)$

$Y = 2R - 8 + 2Y$

$-Y = 2R - 8$

$Y = 8 - 2R$

Composition (all vitreous)	Ratio O/Si R	Number of Oxygen Atoms per Tetrahedron: Bridging (Y)	Number of Oxygen Atoms per Tetrahedron: Nonbridging (X)
Fused Silica — SiO_2	2	4	0
Sodium Disilicate — $Na_2O{\cdot}2SiO_2$	2.5	3	1
Vitreous — $Na_2O{\cdot}CaO{\cdot}2.86SiO_2$	2.7	2.6	1.4
Soda-Lime Glass — $Na_2O{\cdot}CaO{\cdot}2.5SiO_2$	2.8	2.4	1.6
Soda-Lime Glass — $Na_2O{\cdot}CaO{\cdot}2.22SiO_2$	2.9	2.2	1.8
Sodium Silicate — $Na_2O{\cdot}SiO_2$	3.0	2	2
Soda-Lime Glass — $Na_2O{\cdot}CaO{\cdot}2SiO_2$	3.0	2	2

effort to show anything other than the changes in the SiO_4 network and the increase of open ends in this network or of single bonded oxygens in the network. The sodium or calcium ions are not shown, but they occupy the holes on basis of size, distortion, electrical nature and screening, etc.

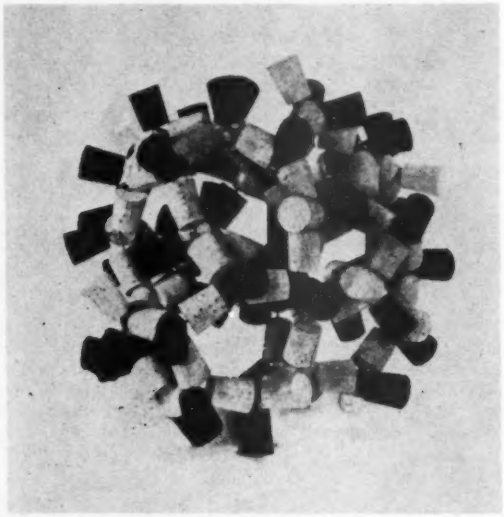


Fig. 27. A three-dimensional model of the network of a glass for which Y = 3. This means there are three bridging oxygens (white corks) and one nonbridging oxygen (black corks) per one tetrahedron. (Ref. 14)

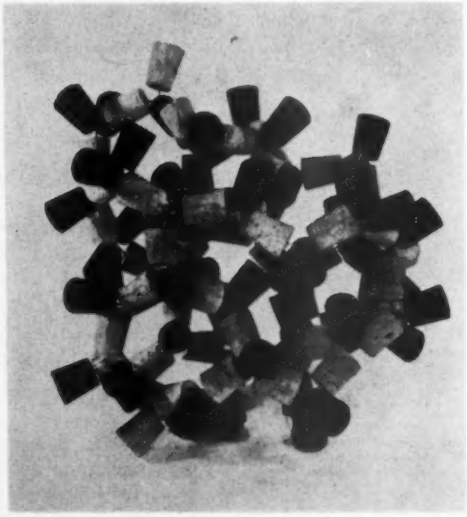


Fig. 28. A three-dimensional model of the network of a glass for which Y = 2.6. See Fig. 27 for explanation. (Ref. 14)

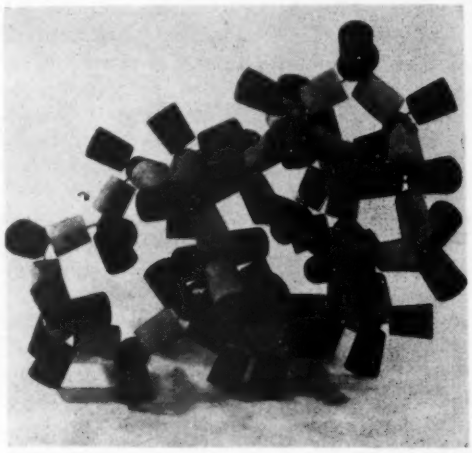


Fig. 29. A three-dimensional model of the network of a glass for which Y = 2.2. See Fig. 27 for explanation. Compare the progression of the openness of the structure from Figs. 27 to 28 and to 29. (Ref. 14)

Thus, while the additional oxygen is included in the fundamental linkage, sodium oxide or calcium oxide enters the holes in the network as ions. Fundamentally, therefore, glass becomes ionic in nature, and this ionic nature is what gives it conduction at high temperature. However, at room temperature the ions are so restricted in their movements that we get an insulator. From the standpoint of structure, the SiO_4 unit is one of covalency (see Section 4.3) and we can consider the basic structure as covalent. However, glass must be considered as ionic to some degree (see Section 4.2).

e. Glass as a Polymer

(References 10, 12, 34, 35, 36, 37, 39, 46) The single SiO_4 tetrahedron has a maximum dimension of about 3 Å because it is made up of oxygen-to-oxygen contact and each oxygen has an ionic radius of approximately 1.35 Å ((Fig. 8). When, however, the unit builds up into larger structures such as might be represented by Si_2O_7 or perhaps as Si_6O_{18}, we can get dimensions from 7 up to 10 Å or more (Fig. 22). We do not know just exactly how large the structural units in the glass can be. The nearest form of a crystalline type of structure is that of SiO_2 in the form of cristobalite, in which the unit cell is approximately 7 Å, but even here it is doubtful whether one unit cell may be designated as a crystal. We therefore now commonly accept the theory that the structure

(*Continued on page* 228)

Inventions and Inventors

Annealing and Tempering

Method of Making Ophthalmic Lens. Patent No. 2,796,000. Filed November 8, 1952. Issued June 18, 1957. One sheet of drawings; none reproduced. Assigned to The Univis Lens Company, by George A. Beasley.

This invention contemplates the making of a cataract lens by the forming of a temporary composite lens blank by joining two standard main blanks of optical glass at mating optical surfaces thereon, and by then grinding a third optical surface on the composite blank so as to intersect the mating surface, of the main blanks. Such intersection of surfaces causes one of the main blanks to become ring-shaped; this ring-shaped main blank is then disconnected from the other main blank at their cemented joining surfaces. The resulting ring-shaped blank is then permanently fused to a third main blank of optical glass which is provided with an optical surface adapted to mate with one of the optical surfaces on the ring-shaped blank. The result is a permanent composite blank with extra thickness near its periphery. Such extra thickness permits the grinding of a relatively highly curved optical surface on the front surface of my composite blank, with the blank at the same time being relatively thin throughout its central area.

There were 4 claims and the following references cited in this patent: 795,425, Bowers, July 25, 1905; 1,395,303, Walsh, Nov. 8, 1921; 2,052,825, Haussmann, Sept. 1, 1936; 2,053,551, Culver et al., Sept. 8, 1936; 2,447,068, Hammon, Aug. 17, 1948; 2,517,609, Tillyer, Aug. 8, 1950; and 2,518,099, Tillyer, Aug. 8, 1950.

Feeding and Forming

Glass Making Machine with Dual Cylinder Press Plungers. Patent No. 2,783,591. Filed December 5, 1955. Issued March 5, 1957. Five sheets of drawings; none reproduced. Assigned to Lynch Corporation by Charles A. E. Johnson.

This invention relates to a glassmaking machine having dual cylinder press plungers.

An arrangement of hydraulically operated press plungers is provided for a glassmaking machine in which two articles at a time can be handled at a pressing station of the machine by an arrangement of two press plungers to enter a pair of molds and press the ware therein to shape. The plungers are individually hydraulically controlled and coordinated in their action by inter-connected hydraulical motors in the hydraulic supply lines to the cylinder and piston mechanisms that operate the plungers; the motors can be disconnected in case only one of the plungers is to be used.

A further object is to provide kick-up mechanism at the take-out station of the glassware forming machine for elevating the ware out of the mold so that take-out tongs can cooperate in removing the ware from the machine.

There were 25 claims and the following references cited in this patent. 682,906, Blue, Sept. 17, 1901, and 473,270, Germany, Mar. 13, 1929.

Furnaces

Process and Apparatus for Purifying Glass. Patent No. 2,781,411. Filed June 4, 1954. Issued Feb. 12, 1957. One sheet of drawings; none reproduced. Assigned to Jenaer Glaswerk Schott & Gen. by Walter Geffcken and Marga Faulstich.

This invention refers to a process of purifying or refining glass.

The glass is melted down at normal pressure. Upon attainment of the desired purifying temperature of the glass melt by the Joule heating, the pressure is lowered to from 0.70 to 0.95 atm. In this way, a vehement development of gas results, the intensity of which is regulated by adjusting the pressure so that the glass just does not boil over. Through a window provided in the vacuum furnace containing the crucible, the refining process can be continually observed because the external temperature of the furnace remains sufficiently low.

Purification is completed when the melt no longer gives off bubbles, a condition which will be attained in from a quarter to half an hour. A further advantage of the process of this invention and one which is conditioned by the generation of the heat directly inside the melt is that if a ceramic melting or protective crucible is provided, this crucible can be reinforced with non-scaling steel, inasmuch as its external temperature remains so low as to lengthen the life of the crucible materially.

If the melt is contained in an electrically conductive crucible, then this crucible can be used as an electrode. The electrodes consist an advantage to a material which does not form gases when in contact with the melt at the necessary purifying temperature. Examples of such materials are molybdenum, tungsten, and the platinum metals or their alloys.

An advantage of the process is that by reason of the Joule effect heating, powerful convection currents arise in the melt thereby continually causing other portions of the fluid glass to come to the surface. As is well known, bubbles expand and escape much more easily at the surface than in deeper zones.

There were 9 claims and the following references cited in this patent: 805,139, Hitchcock, Nov. 21, 1905; 1,564,235, Harrington, Dec. 8, 1925; 1,601,523, George, Sept. 28, 1926; 2,280,101, Slayter et al., Apr. 21, 1942; 2,286,903, Dockerty, June 16, 1942; 2,314,956, Slayter et al., Mar. 30, 1943; and 16,541, Netherlands, July 15, 1927.

Glass Compositions

Glass Composition. Patent No. 2,776,900. Filed December 16, 1953. Issued January 8, 1957. No sheets of drawings. Assigned to Pittsburgh Plate Glass Company by James E. Duncan and Samuel L. Seymour.

The present invention relates to a family of glass compositions suitable to provide a series of opaque glasses having permanent pastel colors ranging from yellow to tan. These glass compositions provide a set of colors

that are pleasing to the eye and enhance the beauty of a structure whose walls are covered with a glass of this type.

Typical glass compositions which can be provided with the proper permanent coloring contain:

	Per cent by weight
SiO_2	55 to 75
Na_2O	0 to 15
K_2O	0 to 15
Total alkali metal oxides	11 to 21
Al_2O_3	2 to 12
One or more bivalent metal oxides from the group consisting of CaO, Mgo, BaO, and ZnO	
Sb_2O_5	0 to 12
As_2O_5	0 to 2
Gold	.0005 to .0024
Silver	.0004 to .0050
Selenium	.0002 to .002
Fluorine	1 to 6

The Al_2O_3 increases the working range of the glass. If more than 12 per cent Al_2O_3 is included in the glass, an excessive amount of alkali and flourine is required to compensate for the excess stiffness imparted to the glass by the alumina.

Flourine is used as an opacifying agent. It is preferred to have between 2.5 per cent and 3.0 per cent F_2 in our glass although as high as 6 per cent or as low as 1 per cent may be used.

Up to 10 per cent CaO may be employed. CaO tends to produce a more uniform opacity with smaller fluoride crystals. Other bivalent metal oxides such as MgO, ZnO and BaO may also be substituted for part or all of the CaO. When such substituted bivalent metal oxides are used, the maximum total weight of the bivalent metal oxides may be increased to about 12 per cent.

Arsenic and antimony are used as refining agents to aid in removing undissolved gases in the molten glass. More than 2 per cent of either refining agent does not appear to be beneficial to the finished glass composition.

The amount of fluorine present in the glass composition must be delicately balanced with the amount of gold, silver and selenium present. If too much fluorine is included, the glass will opacify too rapidly, thereby forming an opaque glass having a lighter color than that desired. On the other hand, too little fluorine compared to the other colorants results in a colored glass having a milky, translucent appearance instead of the desired opacity.

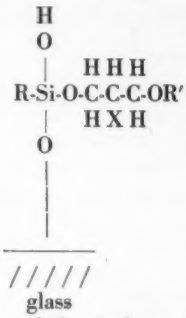
There were 6 claims and the following references cited in this patent: 2,515,275, Stookey, July 18, 1950; 2,515,936, Armistead, July 18, 1950; and 2,651,145, Stookey, Sept. 8, 1953.

Glass Wool and Fiber

Method of Coating Glass Fibers. Patent No. 2,776,910. Filed February 10, 1954. Issued January 8, 1957. No sheets of drawings. Assigned to United States of America by Porter W. Erickson and Irving Silver.

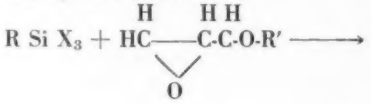
This invention relates to chemical finishes for improving adhesion between the resin and reinforcement in reinforced plastics and more particularly to improved chemical finishes for increasing the adhesion between glass fibers used as reinforcements in epoxy resin laminates and to the method of applying such finishes.

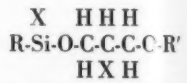
The general structure of these finishes is presumed to be



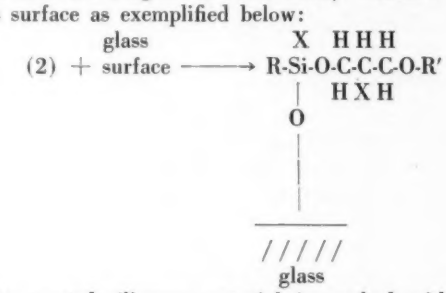
in which R is a methyl, vinyl, or allyl group, R′ is an allyl or methacrylyl group and X is a halogen.

Finishes of the general structure 1 result from the treatment of a siliceous material with the reaction product of a halosilane and a glycidol derivative as exemplified by the reaction





The product 2 of the reaction above is then diluted to substantially 5 per cent or less in a nonpolar organic solvent, preferably xylol, and is used to treat desized glass fabrics or other siliceous filler material with the result that the reagent becomes firmly attached to the glass surface as exemplified below:



The treated siliceous material is washed with xylol several times and then air dried. Thereafter the treated stock may be given a water rinse, resulting in the structure 1 indicated above.

There were 18 claims and the following reference cited in this patent: 2,650,934, Rust et al., Sept. 1, 1953.

Sheet and Plate Glass

Methods of and Apparatus for Vertically Drawing Glass in Sheet Form. Patent No. 2,772,516. Filed January 13, 1950. Issued Dec. 4, 1956. Two sheets of drawings; none reproduced. Assigned to Pilkington Brothers Limited by George W. T. Bird.

This invention relates to method of and apparatus for vertically drawing glass in sheet form.

The invention consists in apparatus for regulating the flow in a drawing kiln, which is characterized by an arch formed medially in the under side of a member

extending across the width of the kiln. This member projects above the surface of the metal for the width of the kiln and is immersed in the metal to the aforesaid lower level. The arch is formed to direct the flow of metal passing medially of the kiln in the vicinity of the draw line.

The bottom of the shut-off depends into the metal to a level below that of the underface of the drawbar, the arch formed in the shut-off forward face to form an ambient ridge. The ridge thus formed permits the metal which has been separated from the metal feeding the sheet to be evacuated from the extension to the tank by dispersing laterally towards each wall of the extension under the vertical wall and back into the melting tank. The width of the arch is about a third of the width of extension, and the height is such as to produce a volume of relatively fast moving metal in compensation for the volume of metal taken up by the sheet moving up into the tower. In such a construction the ridge may have either a horizontal upper face or a sloping upper face.

By this invention, metal of practically uniform temperature and viscosity is distributed across the body of the sheet and losses due to warping or breakage during annealing are minimized. Good quality glass free from seeds, foreign particles or "music lines" (such as are produced if the metal at the surface and in contact with a shut-off or skim-bar flows into the line of draw) may be continually produced. The following references were cited in this patent: 837,821, Fourcault, Dec. 4, 1906; 876,276, Colburn et al., Jan. 7, 1908; 1,615,841, Hitner, Feb. 1, 1927; 1,805,218, Mambourg, May 12, 1931; 1,920,692, Halbach, Aug. 1, 1933; 1,956,170, Gregorius, Apr. 24, 1934; 2,291,348, Schaulin, July 28, 1942; and 2,384,073, Campbell, Sept. 4, 1945.

Tube and Cane Machines

Cathode-Ray Tube Envelope. Patent No. 2,782,952. Filed April 13, 1954. Issued February 26, 1957. One sheet of drawings; none reproduced. Assigned to Corning Glass Works by Robert H. Dalton.

The present invention relates to glass-to-metal seals wherein complementary endless surfaces of two glass parts, for example, the funnel and panel members of a television picture tube envelope assembly, may be separately joined to metal strip and the sides of the strips opposite to which the members are sealed brought together and then sealed to one another to provide a hermetic seal between the panel and funnel members.

Two glass members, such as the panel and funnel members of a television picture tube, as ordinarily adapted to be directly welded to one another to form a completed picture tube envelope, can conveniently have their sealing surfaces separately joined by a suitable sealing glass to aluminum sealing strips, after which such parts may be brought into register and the aluminum strips welded to one another along an area laterally disposed from the glass-aluminum seals to complete a seal between such parts.

The strips have the inner regions of their surfaces sealed to the panel and funnel after which the panel and funnel are arranged with their strips in sealing relation and with a gasket interposed between their opposing surfaces. The abutting surfaces are then welded to one another to effect the hermetic seal. Obviously, the gasket reduces point loading along the seal line when the finished tube is evacuated and is conveniently made of a thickness corresponding to the spacing between surfaces to reduce distortion of the strips along the line of juncture of their thick and thin portions.

There were four claims and the following references cited in this patent: 2,423,066, Gibson, June 24, 1947; 2,531,623, Hale et al., Nov. 28, 1950; and 2,635,205, Olson, Apr. 14, 1953.

Miscellaneous Processes

Method of Beneficiating Sand. Patent No. 2,769,540. Filed November 8, 1952. Issued November 6, 1956. One sheet of drawings; none reproduced. Assigned to American Cyanamid Company, by Otto R. Brown.

The present invention relates to an improved process for purifying industrial sands and particularly, glass sands, by froth flotation.

The screened sand is scrubbed violently at about 80 per cent solids and the discharge from the scrubber is diluted to 20 per cent solids with water which may contain hydrofluoric acid. The diluted scrubbed sand is passed over a 20-mesh screen and the undersize material is deslimed, and dewatered in a screw classifier to approximately 75 per cent solids. The effluent water and slimes from the classifier, as well as the oversize from the 20-mesh screen are sent to waste.

The sized and scrubbed sand is conditioned at high solids with about 0.45 lb./ton sulfuric acid, 0.40 lb./ton fuel oil, 0.55 lb./ton of a water-soluble petroleum sulfonate, 0.45 lb./ton of an oil-soluble petroleum sulfonate, and about 0.01 lb./ton of pine oil. The pH of the conditioned sand is approximately 2.5, depending on the alkaline material present in the feed. The conditioned sand is diluted with water to about 25 per cent solids and separated mechanically into at least two parts. This mechanical separation may be made either before or after the iron flotation step. The iron concentration may now readily be floated off in separate flotation cells and the iron-float tailings recovered in better than 95 per cent yield. The iron assay of these tailings is approximately 0.06 per cent.

A portion of the iron float tailings is dewatered to 80 per cent solids and the excess water returned to the conditioned ore prior to iron flotation. The dewatered tailings are conditioned with about 1 lb./ton hydrofluoric acid, 0.35 lb./ton of a high molecular weight aliphatic amine acetate, 0.5 lb./ton kerosene, and 0.2 lb./ton pine oil. The pH of the conditioned material is approximately 2.8. This hydrofluoric acid-treated iron tailing is diluted with water to about 35 per cent solid and floated to separate the quartz from the feldspar.

There were 4 claims and the following references cited in this patent: 2,161,010, Breerwood et al., June 6, 1939; 2,409,665, Cole et al., Oct. 22, 1946; 2,483,192, Gieseke, Sept. 27, 1949; 2,536,058, Houston, Jan. 2, 1951; 482,931, Great Britain, Apr. 7, 1938. Other references: Mine and Quarry Engineering, March 1941, pages 69-73.

Packing Container for Curved Glass. Patent No. 2,769,534. Filed July 12, 1954. Issued November 6, 1956. Two sheets of drawings; none reproduced. Assigned to Studebaker-Packard Corporation by Edward J. Lidgard.

(*Continued on page* 234)

A Study, on Models, of the Effects of Operation and Design on the Glass Flow in Tank Furnaces

• THE AVERAGE DAILY output of a container tank amounts to approximately one third to half its capacity, yet it takes only 5-10 hours for some of the glass to travel from the batch feeding end to the machines. The glass obviously does not move forward as a simple displacement current; some of the glass travels faster, while other portions may become almost stagnant. Being heated from the top, the glass at lower levels in a tank is cooler and more viscous than on the surface. It would appear that the operation and design of glass tanks should aim at the longest possible residence time of glass in the melting end for a given rate of melting, and at bringing the main glass stream nearer to the surface in the refining zone of the melting end, in order to reduce the time required for refining. If this is achieved, the furnace would be able to melt more glass and of better quality, or alternatively it may be operated at a lower temperature. Knowledge of the pattern, rate of flow, and linear speed of currents in existing tanks is essential if any design improvements are to be obtained.

F. W. Preston (1936) and later I. Peyches (1948) gave a comprehensive review of the methods used in the investigation of glass currents. Several authors, starting with G. Gehlhoff (1931), used refractory floaters, the movement of which was observed. Unfortunately, surface currents may not, and usually do not, represent the flow at lower levels where the bulk of glass moves forward.

Movement of glass can also be investigated using tracers. W. M. Hampton (1931) and E. J. S. Bowmaker with J. D. Cauwood (1931) used barium oxide as an addition to batch. By taking samples from feeders and working holes, they were able to establish the presence of convection currents, and tried to reconstruct the pattern of these currents. F. L. Bishop (1945) used ceria as a tracer, and although this method shows only the "end results" of the currents, i.e. the timing of the arrival of new glass at various points, he was able to make progress by following, on commercial tanks, the results of design changes as well as the effects of operation factors (e.g. position of the 'thermal barrier') (F. L. Bishop, 1956).

The pattern of currents can be observed in transparent models of tank furnaces. Such models, built to scale and operated at a room temperature, can be quickly and cheaply constructed, the effect of changes in operating conditions can be followed and modifications can be studied. Without the help of the model technique design improvements have to be slow and gradual, for reasons of economy and of risk to production. This has been recognized in the aircraft industry, in shipbuilding and civil engineering where scale models have been applied with a remarkable degree of success.

A. C. Flint & A. K. Lyle (1932) experimented with models, using water to represent glass. A. Schild (1933) used scale models of glass tanks filled with glycerine; he attempted to obtain similarity of flow and of heat transfer. F. W. Preston (1936) expressed doubts as to the validity of model tests and E. Buckingham (1937) gave a review of similarity requirements, pointing out the difficulties involved. In post-war years model technique in furnace design was used by the Russians who developed it primarily for steel furnaces. A. A. Sokolov (1950) investigated on models the formation of stagnant areas in window tanks and also reported on a study of currents in tank furnaces, carried out by the Glass Research Institute in Moscow. I. Peyches (1948) used 1:10 scale models filled with glycerine, or other viscous liquids, to represent the molten glass. He tried different methods of heating the "glass": by radiation from the surface, by hot jets, or by immersed heaters.

Attractive as is the use of models this technique would be of little value unless what is observed or measured in a model is a true representation of the process in a full-size furnace. It has been observed that the relationships between variables in natural phenomena, such as heat transfer and fluid flow, appear to be governed by dimensionless ratios of the variables involved (Walker and others, 1937). The relationships between the variables are independent of the systems of units used. The number of the dimensionless ratios involved depends on the number of fundamental dimensions. If it could be decided which of the factors involved in a given process are important and which could be neglected, the relationships would be simplified and the number of dimensionless criteria reduced. Providing the values of these dimensionless criteria or numbers are the same in the model and its full-scale equivalent—the processes are similar (Rosin, 1939; Thring, 1947, 1948).

The task of establishing similarity criteria for glass flow in tanks is made difficult by the large number of the independent and dependent variables involved. If all the variables are considered, as was tried by E. Buckingham (1937), the number of dimensionless ratios required for similarity would be at least four and it would be extremely difficult to satisfy all of them simultaneously on a model. It is necessary, therefore, to make some simplifying assumptions and to neglect some of the variables.

S. Kruszewski in the August 1957 issue of the *Journal of the Society of Glass Technology* describes some preliminary results obtained by the use of model furnaces in which similarity criteria were a first consideration.

The models used were of 1:20 scale, and were made of Perspex. The liquid was fed at a controlled rate into two 'dog-houses' in the gable wall, and was withdrawn from three 'spouts' or 'feeders' in the rectangular working end.

Heating was by radiation from narrow, flat, electric resistance elements which were located in positions corresponding to ports in a tank. The working end was heated by a large rectangular electric resistance element covering all the working end area, thus giving a uniform temperature distribution. The power supply to each of the heaters as well as their positions were adjustable.

(*Continued on page* 244)

Current Statistical Position of Glass

Employment and payrolls: Employment in the glass industry during January, 1958 was as follows: *Flat Glass*: A preliminary figure of 27,700 for January, 1958 indicates a decrease of 6.1 per cent from the adjusted 29,500 reported for December, 1957. *Glass and Glassware, Pressed and Blown*: A decrease of 3.6 per cent is shown by the preliminary figure of 75,200 reported for January, 1958, when compared with the adjusted figure of 78,000 recorded for December, 1957. *Glass Products Made of Purchased Glass*: The preliminary figure of 12,500 given for January, 1958 indicates a decrease of 6.7 per cent from the previous month's adjusted figure of 13,400.

Payrolls in the glass industry during January, 1958 were as follows: *Flat Glass*: A decrease of 7.5 per cent is shown in the preliminary $14,088,428.86 when compared with December, 1957's adjusted $15,218,718.27. *Glass and Glassware, Pressed and Blown*: A decrease of 4.6 per cent is shown in the preliminary $27,334,851.82 reported for January, 1958 when compared with the previous month's adjusted $28,650,055.98. *Glass Products Made of Purchased Glass*: A preliminary figure of $3,761,585.63 was reported for January, 1958. This is a decrease of 10 per cent when compared with the adjusted figure of $4,184,542.75 indicated for December, 1957.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers

	Feb., 1958
Food	889,000
Medicinal and Health Supplies	1,292,000
Chemical, Household and Industrial	694,000
Toiletries and Cosmetics	763,000
Beverage, Returnable	1,322,000
Beverage, Non-Returnable	124,000
Beer, Returnable	95,000
Beer, Non-Returnable	464,000
Liquor	706,000
Wine	312,000
Sub-total (Narrow)	6,661,000

Wide Mouth Containers

Food	*2,728,000
Medicinal and Health Supplies	555,000
Chemical, Household and Industrial	138,000
Toiletries and Cosmetics	281,000
Packers' Tumblers	45,000
Dairy Products	138,000
Sub-total (Wide)	3,885,000
Total Domestic	10,546,000
Export Shipments	225,000
TOTAL SHIPMENTS	*10,771,000

*This figure includes Fruit Jars and Jelly Glasses.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production Feb., 1958	Stocks Feb., 1958
Food, Medicinal and Health Supplies; Chemical, Household and Industrial; Toiletries and Cosmetics	Narrow Neck	3,861,000	6,689,000
	Wide Mouth	*3,960,000	*5,830,000
Beverage, Returnable		1,062,000	1,645,000
Beverage, Non-Returnable		92,000	214,000
Beer, Returnable		187,000	499,000
Beer, Non-Returnable		537,000	870,000
Liquor		659,000	1,332,000
Wine		327,000	713,000
Packers' Tumblers		63,000	98,000
Dairy Products		151,000	306,000
TOTAL		*10,899,000	*18,196,000

*This figure includes Fruit Jars and Jelly Glasses.

Glass container production: Production based on figures released by the Bureau of the Census was 10,899,000 gross during February, 1958. This represents a decrease of 6.9 per cent from the previous month's production of 11,714,000 gross. During February, 1957, glass container production was 11,057,000 gross or 1.4 per cent above the February, 1958 figure. At the end of the first two months of 1958, glass container manufacturers have produced a preliminary total of 22,613,000 gross. This is 0.6 per cent below the 22,755,000 gross produced during the same period in 1957.

Shipments of glass containers during February, 1958 came to 10,771,000 gross, or a decrease of 1 per cent from January, 1958 shipments which were 10,879,000 gross. Shipments during February, 1957 amounted to 9,899,000 gross or 8.7 per cent below February, 1958. At the end of the first two months of 1958, shipments have reached a preliminary total of 21,650,000 gross, which is 6.6 per cent over the 20,211,000 gross shipped during the same period the previous year.

Stocks on hand at the end of February, 1958 came to 18,196,000 gross. This is .8 per cent above the 18,051,000 gross on hand at the end of January, 1958, and 13 per cent higher than the 16,107,000 gross on hand at the end of February, 1957.

C. J. BACKSTRAND NAMED DIRECTOR AT PITTSBURGH PLATE

Pittsburgh Plate Glass Company has announced the election of Clifford J. Backstrand as a member of the Board of Directors. As a director he succeeds Richard B. Tucker, who resigned.

Mr. Tucker has been associated with the glass industry for more than 50 years. His association with Pittsburgh Plate Glass Company began in 1929 and he had served as a director since 1942. He retired as a vice president at the end of 1956.

Mr. Backstrand has been president of Armstrong Cork Company since 1950, and has served as a director of that company since 1935. He also is a director of the Bell Telephone Company of Pa., and a director of the Hamilton Watch Company.

A native of Los Angeles, California, Mr. Backstrand has been associated with Armstrong Cork Company since 1921. He resides at Lancaster, Pennsylvania.

New Equipment and Supplies

HIGH PURITY SILICA, 0.005 PER CENT Fe_2O_3

International Minerals & Chemical Corporation, Consolidated Feldspar Department, 20 North Wacker Drive, Chicago 6, Ill., has available, it is said, the highest purity low iron silica produced in this country. Kona Quintus Quartz is helpful in the production of many types of special purpose glasses such as ultra-violet or infrared ray transmitters, fused quartz, special optical glasses and high clarity tableware. It has advantages in applications in silicate chemistry, catalytic petroleum cracking, production of synthetic chemicals and minerals.

Typical chemical analysis:

Al_2O_3	0.040
Fe_2O_3	0.0034
Na_2O	0.013
K_2O	0.0098
TiO_2	0.001

Typical screen analysis:

Mesh	
50	Tr.
60	.7
70	5.0
80	13.6
100	21.3
140	40.1
200	13.6
−200	5.7

Samples are available for testing and evaluation. In carload or truckload lots the silica is priced at $78.00 per ton.

EXPLOSION-PROOF TEMPERATURE CONTROL

United Electric Controls Company, 79 School Street, Watertown 72, Mass., has available an explosion-proof dual switch temperature control. The instrument is a sensitive remote bulb temperature control designed for use where explosive vapors and gases are present. Two separate switches permit action above or below the set point, control of two independent circuits and great flexibility of switching arrangement, according to the company.

Temperature settings are made by rotating a single turn knob and pointer over a calibrated dial. Individual adjustment of switches is accomplished by independent recessed hex-head screws which provide for approximately 15°F. span, constantly maintained throughout the control range, between switch settings. Other spans are available.

The thermal system consists of a bulb, capillary, and bellows filled with temperature sensitive liquid. The bellows expands or contracts with heating or cooling, thus actuating a snap-action switch at a preset temperature point. Standard head compensation provided is effective from −65° to +160°F.

NON-COOLED DOUBLE REVERSING VALVES

Blaw-Knox Company, 300 Sixth Avenue, Pittsburgh 22, Pa., has introduced a new non-cooled doubledeck reversing valve designed for use in glass furnaces.

Maximum life at minimum cost can be built into the valves, according to the company, by varying the alloy steels from which they are fabricated. The valves can be designed for various operating temperatures. No cooling water is required.

The valve seat is made of cast alloy steel sections which are bolted together and into place in the walls of the flue. Surfaces are machined for a tight fit with the damper. All contact surfaces of the damper, which is sectionally constructed to give it flexibility, are also machined reducing leakage. The damper sections hang from keyed couplings, designed to insure maximum protection from failure.

The company furnishes the complete package, including the valve seat, damper, hood, lifting mechanism and all required engineering.

NEPHELOMETRY TOOL FOR LABS

Fisher Scientific Company, 498 Fisher Building, Pittsburgh 19, Pa., has designed four permanently stable references covering the range from almost clear solutions to turbidities normally found in nephelometric studies. These references, it is claimed, are not subject to the instability inherent in suspensions of solids in liquids; they are microscopic dispersions of one liquid in another, the liquids having the same specific gravity. Each comes in a turbidimetric cell sealed with a plastic cap which identifies the increasing order of turbidity. The cells fit the compartment of the company's Nefluoro-Photometer which is said to combine three precision instruments: nephelometer, fluorometer and colorimeter. The instrument takes only 60 seconds for readings of any of scores of organic, inorganic, synthetic and biological materials.

NEW BUBBLER SYSTEM

The Penberthy Electromelt Company, 4301 Sixth Avenue South, Seattle 8, Wash., has announced development of a glass process improvement in the form of a bubbler system.

The system introduces carefully controlled quantities of treated air in the form of bubbles, into the bottom of a glass tank through a specially designed bubbler tube. As the air bubbles rise to the surface, a rolling action is created in the glass bath. This action brings the more viscous bottom glass to the surface and thereby reduces top to bottom temperature differential. The system is said to produce four major benefits. It improves glass homogeneity, increases product output, lowers seed count, and decreases firing temperature, and is claimed to be especially beneficial in colored glass furnaces.

CATALOGS RECEIVED

Walsh Refractories Corporation, 201 Ferry Street, St. Louis 7, Missouri, has prepared a compilation entitled, "For Your Convenience . . . A Competitive Brand Sheet of Firebrick and Refractory Specialties". Brand names of leading refractories manufacturers are tabulated in easy-to-read form under the general headings of firebrick, cements, castables, plastics and miscellaneous. The tabular data is printed on letterhead size stock for convenience in filing and for ready reference. Copies obtainable from the company.

The Pyrometer Instrument Company, Inc., Bergenfield, N.J., has released a 8 page illustrated general bulletin, Catalog No. 175. The new bulletin describes the company's optical, micro-optical, radiation, immersion, surface and indicating pyrometers; models, accessories, specifications, other technical data and prices are included. Write direct to the company.

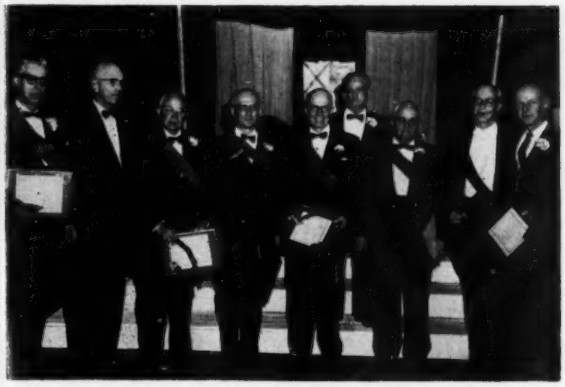
Sturtevant Mill Company, Harrison Square, Boston 22, Mass., offers a new technical bulletin describing the company's Micronizer grinding machine. The 4 page bulletin describes fluid energy grinding and gives typical grinding data for various materials. Information is also given on how to obtain custom or experimental fine grinding service. A cross-section drawing of the micronizer is shown, and a flow sheet of a complete fluid energy grinding unit is included in the bulletin. Sizes, pressure requirements and capacities are tabulated.

Philips Electronics, Inc., Instruments Division, 750 South Fulton Avenue, Mount Vernon, New York, has issued a new 6 page folder entitled "A High Resolution PMR X-ray Microscope with Electron Microscope Conversion".

The text was prepared by physicist Irwin I. Bessen and gives complete scientific details on the new instrument said to be the first commercial X-ray microscope which determines the chemical composition of the specimen. Information covers the construction of the new instrument as well as its application. Specific sections treat such subjects as components, nature of spectra, absorption analysis, and results obtained.

R. K. DAY AND N. J. KREIDL HONORED AT ALFRED U. FESTIVAL

Dr. Ralph K. Day, development engineer in charge of glass quality evaluation at Libbey-Owens-Ford Glass Company, Toledo, Ohio, and Dr. Norbet J. Kreidl, director of chemical research at Bausch & Lomb Optical Company, Rochester, were honored at Alfred University's St. Pat's Festival, March 15, when they were knighted into the Guard of St. Patrick.



Shown at the formal ball which concluded activities of the 26th annual St. Pat's Festival at Alfred University on March 15 are, left to right: Milton Burdick of the National Bureau of Standards, Washington, D. C.; President M. Ellis Drake of Alfred University; Donald Hagar, Donald Hagar Company, Zanesville, O.; Charles Pearce, General Secretary of the American Ceramic Society, Columbus, O.; Dr. R. K. Day, Libbey-Owens-Ford Glass Company, Toledo, O.; Dean John F. McMahon of the College of Ceramics; Dr. James T. Robson, Ferro Corporation, Cleveland, O.; Dr. Norbert J. Kreidl, Bausch & Lomb Optical Company, Rochester, N. Y.; and Robert Bassett, Central Commercial Company, Darlington, Pa.

The author of a book on glass research methods and holder of a number of scientific patents, Dr. Day received his Ph.D. in physics at Cal Tech. Among the societies in which he holds membership are the American Ceramic Society and the Society of Glass Technology in England.

Dr. Kreidl is a noted authority on optical glass, structure in glass, and nuclear radiation of glass. He received his Ph.D. in Physics in Vienna and was Director of the Glass Works Schreiber & Nephews at Rapotin, Czechoslovakia from 1928-1938. Dr. Kreidl joined Bausch & Lomb Optical Co. in 1943 and in 1953 was President of the U.S.A. Delegation to the International Glass Congress.

"St. Pat" performed the knighting ceremony during the Grand Ball climaxing the 26th annual festival sponsored by students of the State University of New York College of Ceramics at Alfred University. The celebration pays homage to Saint Patrick, the patron saint of ceramic engineers, who is credited with introducing the use of lime and mortar in Ireland. The coveted role of "St. Pat" was awarded this year to Stephen Saunders of Wakefield, Mass., a senior in Ceramic Engineering.

• American Potash & Chemical Corporation has opened a south-central district sales office at Shreveport, La., to handle the company's expanding interests in the states of Louisiana and Mississippi and parts of Alabama, Texas, Oklahoma and Arkansas.

INTERNATIONAL MINERALS OPENS NEW RESEARCH LAB

International Minerals & Chemical Corporation, has put into operation a new research laboratory at Bartow, Fla., designed to "capitalize to the fullest on today's rich new opportunities in minerals."

Dr. I. M. LeBaron, IMC research vice president, said at the opening that the new mineralogical lab, unique in the mining industry, would allow full-range mineral investigations, from studying composition of new-found ores to checking out the economic soundness of mining and marketing them.

"This new facility will be used to discover, develop, and keep on tap information management must have for the quick, correct decisions required to keep up with today's opportunities and markets," Dr. LeBaron said.

The laboratory was described by Norman J. Dunbeck, vice president of IMC's Industrial Minerals Division, as a "valuable additional tool in this division's continuous program of developing new products and improving present ones for our markets."

Equipment for the new laboratory includes facilities for differential thermal analysis, X-ray diffraction, spectography and X-ray spectography, and high-powered microscopic studies.

PITTSBURGH PLATE DEVELOPS TAPE FOR GLASS AND METAL SEALS

A sealing tape for glass-to-metal, glass-to-glass and metal-to-metal bonds, has been developed by Pittsburgh Plate Glass Company Research Laboratories to meet the specified needs of architects for modern curtain-wall building construction, it has been announced. To be known as #1072 Butene Sealing Tape, the black rubbery tape is easily applied from a packaged roll without further processing.

The vulcanized material is said to maintain its elastic and resilient nature while providing long-life weather-tight seals of extreme durability. Extensive field testing of the product over a ten-year period, with exposures to simulated hurricane proportions, show it to be highly resistant to severe service conditions which in the past have caused rapid deterioration of sealing compounds.

The new sealing tape has shown good performance records under continuous exposure to temperature extremes ranging from –45°F to 250° F. It also shows resistance to ultraviolet exposures.

PACIFIC COAST BORAX RECEIVES AWARD

Pacific Coast Borax Company, Division of United States Borax & Chemical Corporation, recently received an award from *Mining World* publication, for an outstanding construction and engineering job of the "Open Pit Mine of the year." The award was accepted on behalf of the Company by W. H. Wamsley, mine superintendent. The open pit mine, located at Boron, California, was started in early 1956 and over 7 million tons of overburden had been removed at the time the main ore body was reached in April of 1957. A formal dedication of the open pit and refining and concentrating plant, constructed at a cost of $20,000,000, was held on November 13, 1957.

(*Continued from page* 220)

of glass is one of a random network based primarily on the SiO_4 tetrahedron built up into somewhat larger polymers or macromolecules which have incomplete, distorted, or broken linkages in many instances.

Since the SiO bonds are the strongest bonds in the glass structure, the lack of symmetry introduces a variation in binding forces from unit to unit. As a result there can be no one temperature where all major bonds break simultaneously. With increasing thermal energy the number of bonds which can break increases gradually. Thus glasses have no specific melting point but are characterized by a softening range. In effect the decreased viscosity resulting from higher temperatures is one of bond breaking to form smaller units.

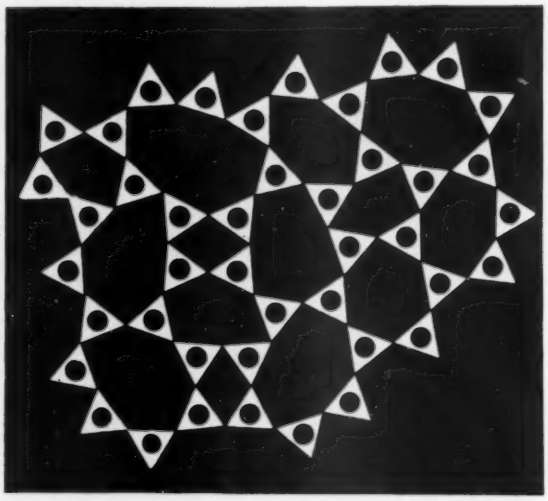


Fig. 30. Constitution of a cohering structure of tetrahedrons in a glass where Y = 3. Each tetrahedron is represented by a triangle, which means that the fourth solid angle is imagined as being outside the plane of the drawing. The junction tetrahedrons are indicated by a black dot. (Ref. 14)

Many physical properties of glass tend to direct us to the fact that we must look upon it as a polymer of fairly large size. Properties such as the dielectric loss, the heat capacity, ect., lead us to conclude that the accepted size of the unit approaches the realm of 20-30 Å or larger. A study of many properites also indicates that we may have to consider the existence of more than one type of structure in glasses. These structures would involve other glass-forming materials and change of coordination of these materials. Properties are explained on the basis of the relative amounts of the two structures. However, to maintain the fundamental glassy properties, these two structures must still act as though they were liquid in nature and they must coexist and intermingle with each other in a liquid type of arrangement.

Recent studies of structure of materials are giving consideration to the distortion of the atoms, thus giving what is known as polarization. A second recent concept is that of "screening," in which a protective electrical action is provided by the screening action of adjacent structures. It is pointed out that the atoms must not be considered as rigid spheres, but as spheres distorted by electrical effects. Similarly, electrical screening is essential to allow stable electron configuration. (References 36 and 46).

Summary of Structure of Glass

Considering the transparency of glasses, we have arrived at the conclusion that glass is a rigid liquid or a mixture of miscible liquids within each other, in which the molecular dimensions approach many times the size of the small SiO_4 tetrahedron. Recent evidence would seem to show that these units of structure approach the realm of 20-30 Å, or perhaps as large as several hundred Å. They are composed of centers of high order approaching that of the crystal, gradually degrading to the exterior, where random order is common and disorder prevails. This is again a picture of a large structural unit where there are varying degrees of order and disorder and where the disorder is so continuous as to compare one unit with another in a fashion considered "polymeric" in nature. These units or macromolecules, if we were to give them a name, are certainly larger than 10 Å and may approach several hundred Å in some cases.

> "Glass belongs to a group of substances in which the arrangement of the component atoms or ions in the linkage possesses a permanence or degree of rigidity similar to that in the crystalline state and an orientation of atomic or ionic groupings quite random in nature, similar to that characteristic of liquids. The degree of randomness, however, may not persist when one considers a size smaller than a few tens or hundreds of Å in linear dimension. It may be described as a solid of a randomly distorted crystalline lattice composed essentially of the same fundamental atomic groupings . . . that has been frozen as such without much crystallization or regular orientation." (Reference 38)

At the present time we believe that glass should be looked upon as a polymer in which the structural units are approaching several times the size of the small SiO_4 tetrahedron.

11. WHY IS GLASS TRANSPARENT?

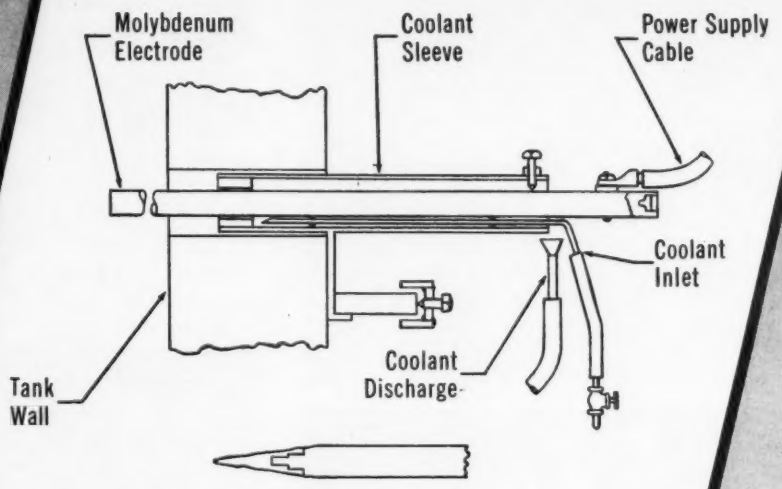
Glass is transparent because:

a. It has no units of structure which are in the realm of visibility by any of the accepted reasons for visibility.
b. It has no surfaces of internal structure which give reflection or refraction or scattering.
c. It has no free electrons which can interact with the electromagnetic nature of wave motion (which includes visible light).

Glass can be made opaque or colored by:

(*Continued on page* 230)

Hot molybdenum ingots are forged into round billets, then further processed to make 1¼-inch diameter electrodes for glass melting furnaces using the Penberthy electrode assembly shown in the diagram.



Electrodes are joined by threaded ends to provide maximum use

Fansteel Molybdenum Electrodes

for electric melting...

here's what they cost:

Based on actual operational costs covering a production of 16,027 tons of flint glass over a period of several months, electrode cost amounted to *only 2½ cents per ton!*

here's what you get:

1. Increased production (10 to 30%)
2. Longer furnace wall life
3. Improved glass quality

FANSTEEL ELECTRODES CAN BE INSTALLED WITHOUT FURNACE SHUT-DOWN . . . are 99.9% pure, give off a colorless oxide, have high thermal and electrical conductivity, and high temperature strength. Write for more complete information.

K577

FANSTEEL METALLURGICAL CORPORATION

NORTH CHICAGO, ILLINOIS, U. S. A.

Glass: Its Transparency . . .

a. Adding gas bubbles or crystals of proper properties and dimensions which will reflect, refract, or absorb light (covers colloidal as well as visible particles).
b. Adding other glassy phases which have different properties from the parent glass and maintain their separate identity (immiscible).
c. Adding coloring ions of other elements that are not normally in glass to give transparent color or almost complete light absorption by density of color alone.

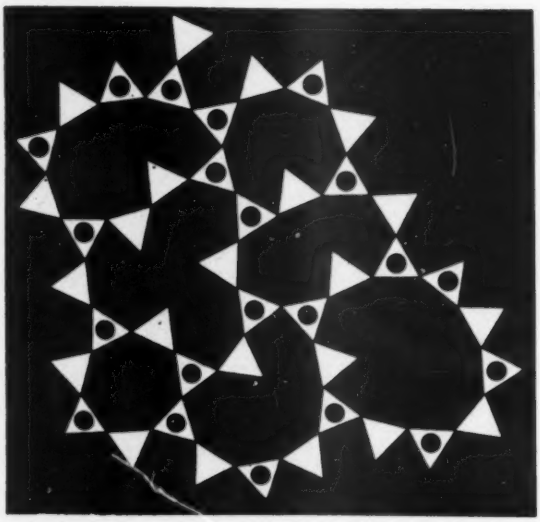


Fig. 31. Constitution of a cohering tetrahedral layer in a glass when Y = 2.5. The tetrahedrons with only two points of contact have no black dot. The "length of the chain" usually averages 3. The structure is more "open" than in Fig. 30. (Ref. 14)

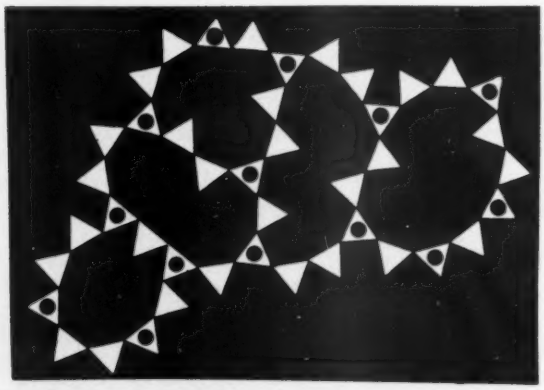


Fig. 32. Constitution of a cohesive tetrahedral layer in a glass when Y = 2-1/3. The tetrahedrons with only two points of contact have no black dot. The "length of the chain" usually averages 4. Compare the structure here, which is more "open" than that in Figs. 30 and 31. (Ref. 14)

References mentioned in this section are listed in the February issue of THE GLASS INDUSTRY, pages 112 and 114.

Errata: In Part I of the above article which appeared in the February issue of THE GLASS INDUSTRY, Table I, page 86, is taken from Reference 30.

Table 2, page 87, is taken from Reference 10, supplemented by the author.

Table 3, page 88, was not taken from Reference 30; but was computed by the author.

G. F. DALEY PROMOTED AT SURFACE

Surface Combustion Corporation, Toledo, Ohio, has announced the appointment of George F. Daley as chief engineer of its Glass Furnace Division.

G. F. Daley

Mr. Daley received a degree in mechanical engineering from the University of Vermont in 1943 and joined Surface in 1945, after three years active military duty. In 1957 he received his Master of Science degree from the University of Toledo.

Daley started in the Glass Furnace Division as a draftsman and later worked in various capacities as designer, estimator and project engineer. With his present duties as chief engineer, goes full responsibility for designs, materials, estimating, development and product improvement of all equipment processed by the Glass Furnace Division.

BOOK REVIEW

Surface Chemistry. Theory and Applications. By J. J. Bikerman, Massachusetts Institute of Technology.

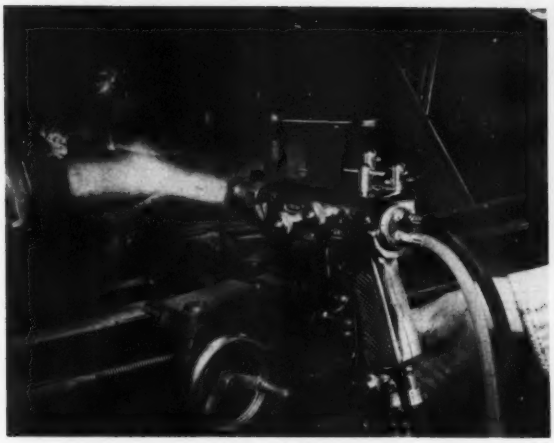
This book refers to many properties of glass. On p. 178 the strength of glass filaments is discussed with reference to *The Glass Industry 29,* 144 (1948). Some data on the surface tension of molten glass are listed, partly based on the publication in *The Glass Industry 33,* 453, 515 (1952). The adsorptive capacity of glasses is treated in seven places. A modern Russian work on the surface conductance of glass and quartz in humid atmosphere is reviewed on pp. 402-403. Also cleaning, contact angles, cord formation, degassing, electrification, electrokinetics, metal films on, surface layer on, surface roughness, and swelling can be found under the heading "Glass" in the Subject Index of the book.

Of course, glass is only one of many classes of materials which are used in the book as examples for the rules or the applications of the physical chemistry of surfaces. It may well be that the sections not dealing with glass will be just as helpful to the glass technologist as those that are, because the properties of surfaces are important at numerous stages of glass manufacture and for numberless uses of glass. For instance, particle size determination can be applied to glass batches, the effect of surface conditions on heat transfer may play a part in every glass tank, and so on.

Second edition, revised and enlarged; 501 pages, 160 figures. Academic Press Inc., New York, N. Y., 1958. Price $15.00.

Here's how to cut production costs

Glass machinery parts last longer with Colmonoy hard-facing alloys*



Making glass machinery parts last longer is the cost-cutting achievement of Colmonoy hard-facing alloys. They are used in many forms, such as oxy-acetylene rod, castings, paste, and powder. Colmonoy serves progressive glass container manufacturers the world over.

Many successful Colmonoy applications are done by the Colmonoy Sprayweld* Process. Here Colmonoy alloys (Nos. 6, 5, or 4) are sprayed on the wearing surface. This overlay is then fused to the base metal with an oxy-acetylene torch. The welded overlay resulting may be ground to mirror-smoothness.

Only Colmonoy Sprayweld alloys contain chromium boride crystals in a nickel alloy base. These powdered alloys are applied with the Colmonoy Spraywelder*, a metal spraying unit that uses compressed air to provide the force needed in building dense, porosity-free deposits. Photo shows the Spraywelder mounted on a tool post, spraying a rotating glass plunger.

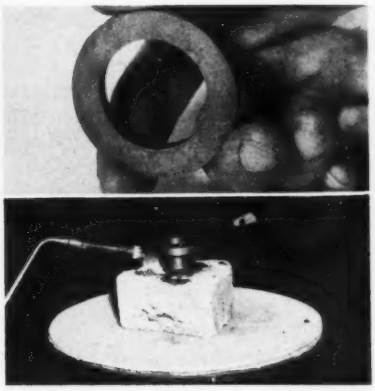
Colmonoy Applications

PART	ALLOY
Cullet Chutes	Colmonoy Sweat-On* Paste, torch fused.
Cullet Hammers	Colmonoy No. 1 electrodes
Timing Buttons	Colmonoy No. 6 oxy-acetylene rod
Blowheads	Colmonoy No. 4 Sprayweld powder
Baffles	Colmonoy No. 4 Sprayweld powder
Glob Cutters	WCR-100 oxy-acetylene rod
Take-out fingers	Colmonoy No. 5 Castings

If your "problem part" isn't mentioned here, tell us what it is, along with information on conditions encountered.

Above are two plungers hard-faced with the Colmonoy Spraywelder and Colmonoy No. 6 alloy, shown before grinding. Inset photo shows finished air-cooled plungers that last 40 times longer with Colmonoy. Request Engineering Data Sheet 43.

Chipped and cracked areas in glass moulds, neck rings, and related cast iron parts are easily repaired with Colmonoy No. 20 oxy-acetylene rod, and are finished by filing. Engineering Data Sheet No. 36 gives full instructions.



Thimble inserts (top) made of Colmonoy No. 4 give cast iron thimbles 3 times longer life. Stock inserts are easily machined to size, are silver soldered (bottom), or press fitted into place. Request Engineering Data Sheet No. 42.

Manufacturing Factories in:

CANADA: 3001 Broadway
Montreal East, Quebec

GREAT BRITAIN: Motherwell
Larnarkshire, Scotland

* Trademarks of Wall Colmonoy Corp.

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in
RAW MATERIALS?

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- **markedly reduced volatile attack and batch carry-out.**
- **longer checker life and furnace efficiency.**

Calumite, in delivering these "extras", helps to eliminate the hidden costs in raw materials.

The Calumite Co.
HAMILTON, OHIO

J. F. McCARTNEY PROMOTED AT HOMMEL

J. F. McCartney

James F. McCartney of Pittsburgh, Pa., has been appointed assistant to the president of the O. Hommel Company, according to a recent announcement by Ernest M. Hommel, president.

Mr. McCartney brings with him a background of broad experience in sales work and will aid in promoting and expanding the company's activities in all phases of the ceramic industry. In this capacity he will work very closely with Hommel's sales and service representatives throughout the United States, with particular attention to the frit division.

Before joining Hommel, Mr. McCartney was vice president and general sales manager of Duff-Norton Co., which position he held for seven years. Prior to his association with Duff-Norton he was a sales representative for Pressed Steel Car Co. He resides in Pittsburgh and will make the home office his headquarters.

BOOK REVIEWS

Optical Industry Directory. This book is an annual which lists about fourteen hundred American suppliers of optical instruments, corrected lenses, raw material, tools, and designing advice. Optical instruments ranging from the X-ray to the far infrared are listed under 394 categories.

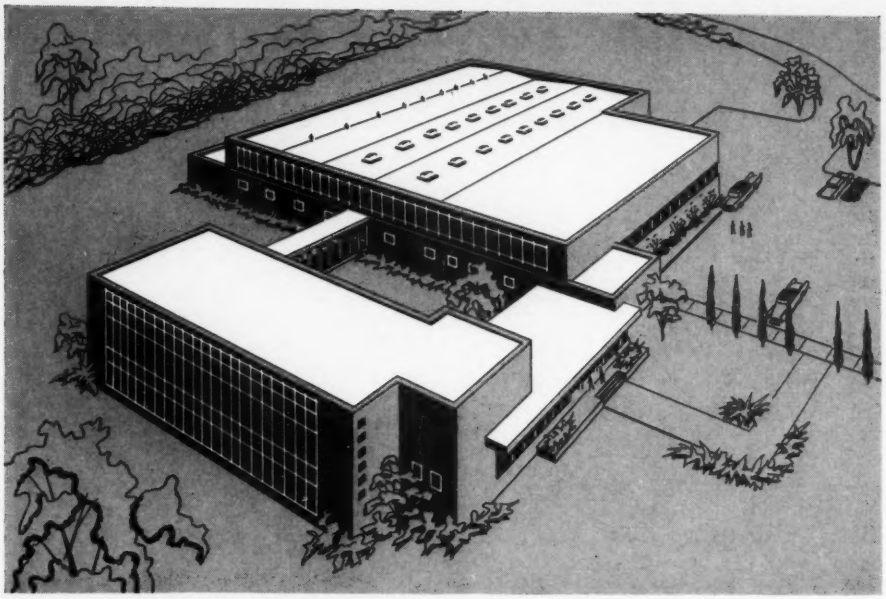
The publishers regard the book as a valuable aid to purchasers and also believe the cumulative index, thoroughly cross-indexed, is the most complete glossary of optical instrumentation which has ever been published.

The personnel listing of interest to the industry, though incomplete, contains the names, affiliations and specialties of about one thousand individuals.

Practically all of the known corrected lenses (about 2,000) manufactured for taking, projection, or viewing are listed as to focal length, aperture, and coverage.

1958 edition, 292 pages, cardboard-bound. The Optical Publishing Company, Box 326, Brewster, N. Y. $5.00 post paid.

Manual of ASTM Standards on Refractories Materials (C-8). This manual includes all 41 ASTM specifications, classifications, methods of testing, definitions, and suggested procedures relating to refractories. It includes revisions to the Society's standards which were published in the previous edition in 1952 plus many additions, and is about 30 per cent larger than the 1952 edition. In addition to the ASTM standards, there is a proposed glossary of terms relating to refractories, their manufacture and use, and lists of standard samples of refractory materials which may be obtained from the National Bureau of Standards. 414 pages, 6 x 9, American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. Paper bound, $5.50; cloth cover, $6.25.



The GARBER RESEARCH CENTER, now nearing completion at West Mifflin, near Pittsburgh, more than doubles Harbison-Walker's research facilities

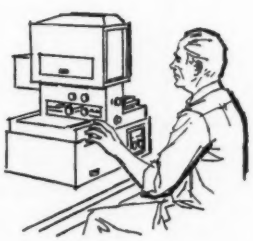
HARBISON-WALKER

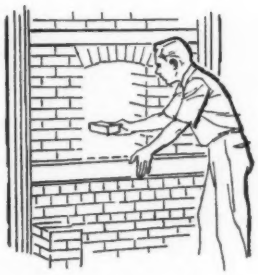
first in refractories through constant research

For more than half a century, vigorous, aggressive research has enabled Harbison-Walker to maintain its leadership in refractories. And today, when accelerated industrial progress is so important, Harbison-Walker is expanding its facilities for this vital activity. Now under construction is the Garber Research Center. When this laboratory, built at a cost far exceeding $1 million, is completed later this year, it will provide the most modern and most complete facilities in the world for the development of new and better refractories for industry.

This research development is just another forward step by Harbison-Walker. Manufacturing facilities have recently been greatly enlarged through the building of new plants and the modernization of existing plants. A highly-perfected quality control program assures the uniformly high quality of all Harbison-Walker products.

Continual development of extensive reserves of raw materials insures uniformity of quality far into the future. Engineering leadership contributes to industrial progress through correct application of refractories. By these accomplishments Harbison-Walker keeps pace with industry's expanding refractories needs.





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Inventions . . .

(*Continued from page* 223)

The present application relates to packing sheet windshields of the curved type having trapezoidally diagonal opposite ends and a body portion of warped or twisted curvature.

An object of the invention is the provision of a cushioning or spacer pack for the interior of glass containers. A two-part construction is employed to produce a glass engaging inner part presenting a plurality of cardboard tunnels to lend twist rigidity to the construction and an outer backing part to impart some resistance to bending of the pack. This is particularly desirable during handling of the pack in installing it in the container. The backing part or panel also incorporates tunnels which extend transversely to the axes of the tunnels of the inner part and which thereby provide a deep twist resistant and bend resistant section to the end pack during handling and other usage.

There were 14 claims and the following references cited in this patent: 1,453,071, Kleeman, Apr. 24, 1923; 2,319,966, Wood et al., May 25, 1943; 2,603,349, Van Antwerpen, July 15, 1952; and 2,665,804, Koester, Jan. 12, 1954.

Production of Cellulated Glass. Fig. 1. Patent No. 2,758,937. Filed March 21, 1952. Issued August 14, 1956. One sheet of drawing. Assigned to Pittsburgh Corning Corporation, by Walter D. Ford.

A cellular glass article is provided which has improved durability, low thermal conductivity, high structural strength for a given density, a finer cell structure and more uniform cell wall thickness. This article is composed of a cellulated body of glass having a plurality of non-communicating cells filled with a gas such as CO_2 and having a metal such as molybdenum, tungsten or vanadium interspersed in and on the cell walls.

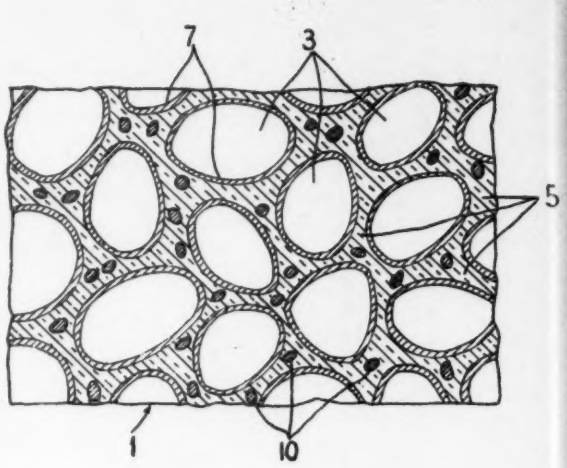
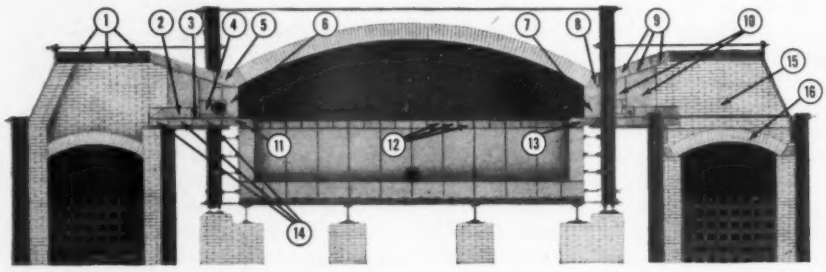


Fig. 1

A sectional view of a slab of the cellulated material is shown in Fig 1. The material is made up of cellulated glass 1 having a plurality of non-communicating cells 3 filled with a gas. The walls 5 of the cells are partially or fully coated with a fine film of metal 7 such as molybdenum, tungsten or vanadium. Also present in the cell

(*Continued on page* 236)



16 PLACES where you can SAVE MONEY IN GLASS MELTING TANKS

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2 Port Baffle
3 Low Pressure Burner Block
4 High Pressure Burner Block
5 Port Lintel Block
6 Port Jambs
7 Upper Structure Side Wall
8 Skewbacks
9 Port Covers
10 Port Sides
11 Port Apron
12 Bridge Covers
13 Tuckstone
14 Port Bottoms
15 Regenerator Side Walls
16 Regenerator Arches.

Additional areas (not shown) include Jambs, Upper Structure Side Walls, Dog House Arch, Dog House Mantel, Backwalls, Feeder Forehearth Super Structure, Tubes and Needles, Checkers and Crowns on Boro-Silicate Tanks.

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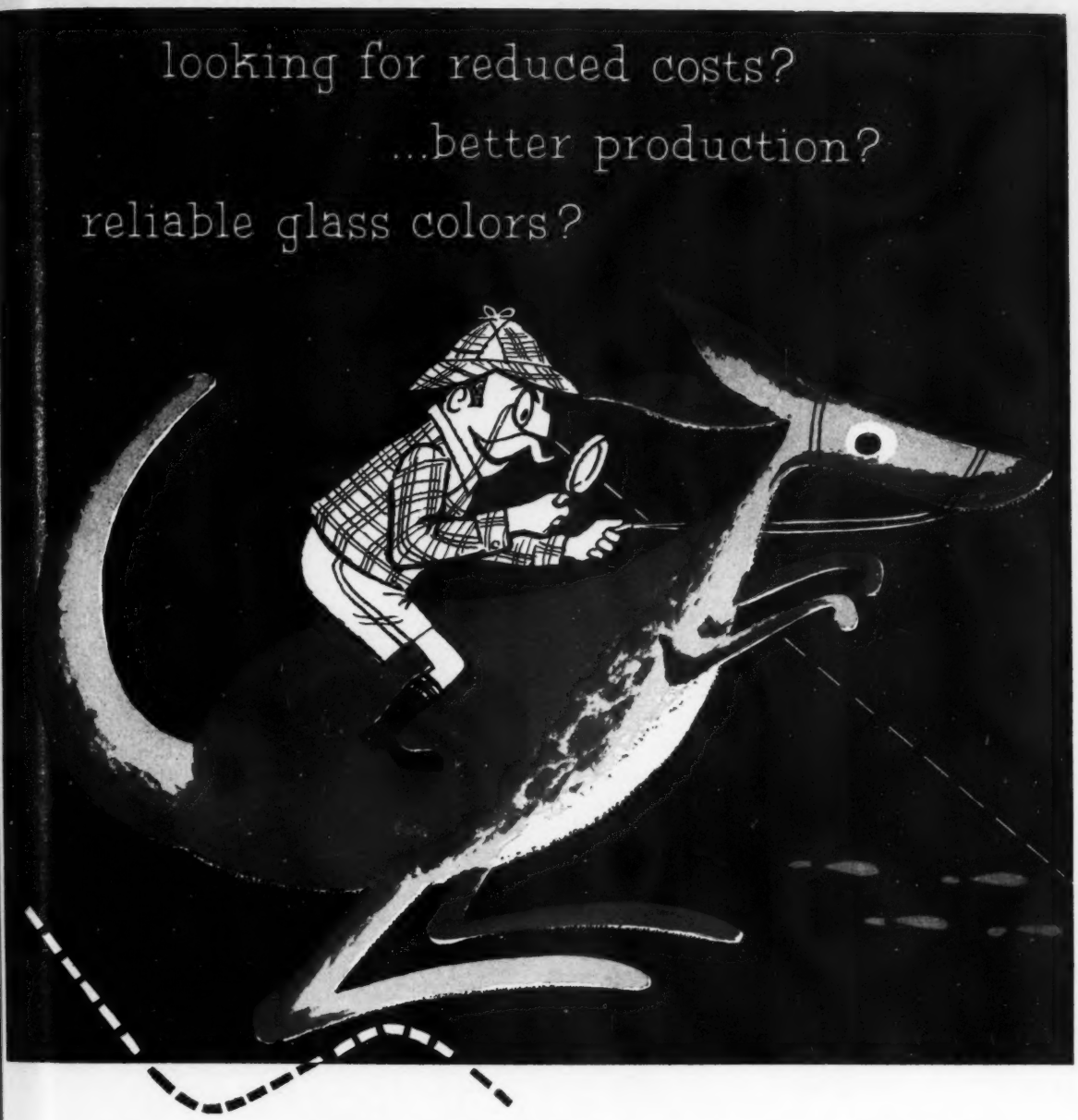

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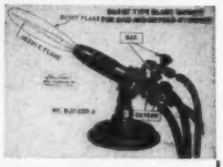

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Charles Eisler, Jr.
President

THE SHARP-SCHURTZ COMPANY

CHEMISTS AND CONSULTING ENGINEERS FOR THE GLASS INDUSTRY

LANCASTER, OHIO U. S. A.

Inventions . . .

(*Continued from page* 234)

walls 5 are small amounts of the metal 7 as shown at 10.

The cellular glass is produced by commingling glass, a gassing agent and an oxide of a metal having a high melting and boiling point such as an oxide of molybdenum, tungsten or vanadium all in pulverulent form; heating the mixture to a temperature at which it sinters and coheres and at which the gassing agent and the metal oxide such as molybdenum oxide react to produce gases which expand to form minute, non-communicating cells within the glass; cooling the cellulated glass; and thereafter annealing it.

There were 15 claims and the following references cited in this patent: 2,399,225, Heany, Apr. 30, 1946; 2,467,528, Hauser, Apr. 19, 1949; and 2,600,525, Ford, June 17, 1952.

Quartz-to-Metal Seal. Patent No. 2,760,310. Filed January 13, 1951. Issued August 28, 1956. One page drawing; none reproduced. Assigned to General Electric Company, by Evan H. Nelson, Harrow Weald, and Jack Whittemore.

This invention relates to quartz-metal seals of the type wherein at least part of the hermetic sealing of a conductive path extending through a quartz body is provided by the sealing of a thin sheet of metal to the quartz.

A seal-body or stem comprises a quartz tube, along which extends a massive rod of refractory metal, such as tungsten or molybdenum, and a thimble of thin platinum metal into which the rod enters (and, if desired, is metallically sealed through an aperture in the base of the thimble). The sealing of the platinum to the quartz is effected around the edge and on the outer surface of the thimble while the sides of the thimble are maintained in good thermal contact with the rod.

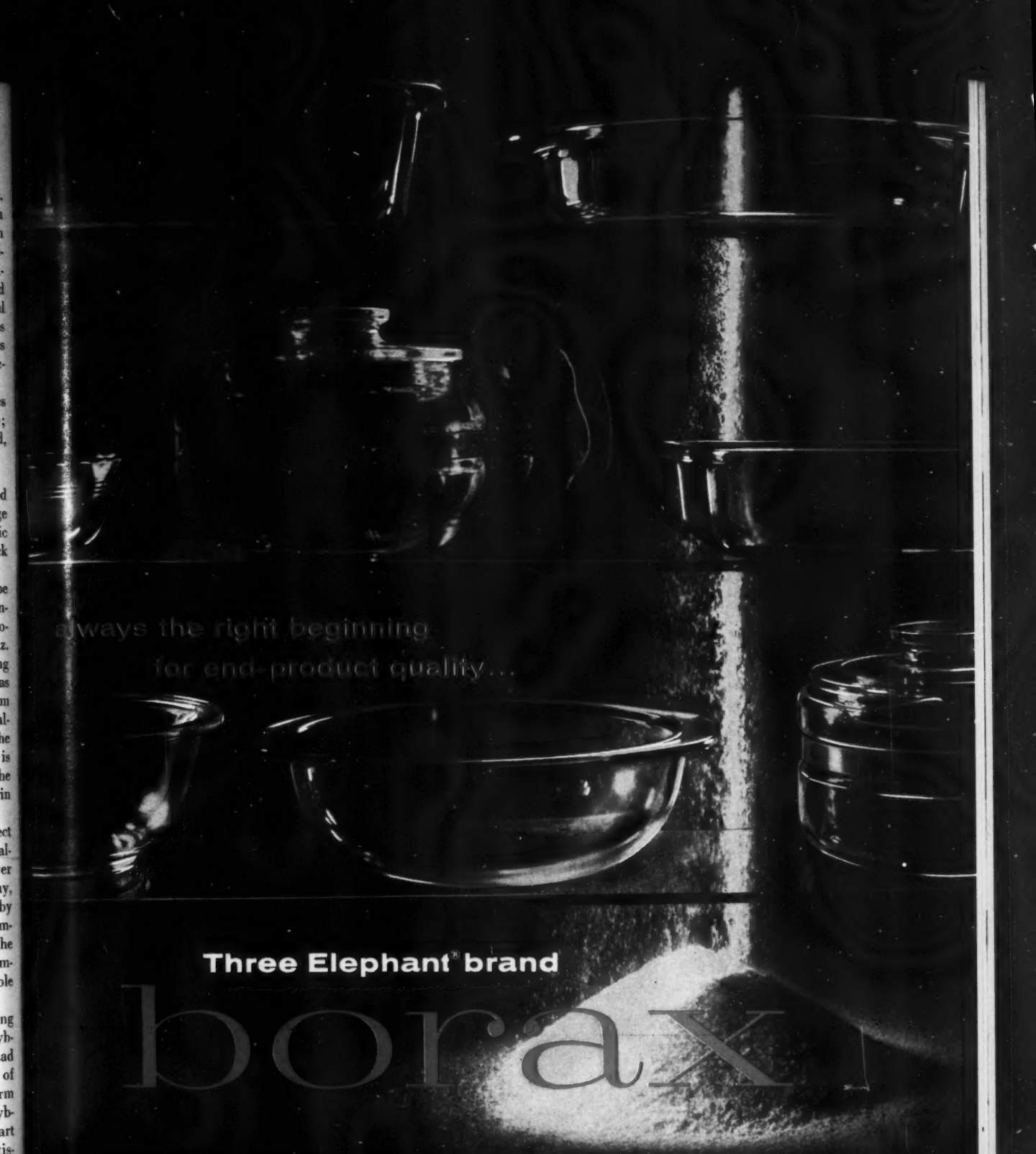
Preferably, the rod conductor is arranged to project beyond the end of the quartz tube in the completed seal-body, and the thimble of platinum is arranged to cover completely the projecting end of the rod. In this way, no part of the rod conductor is exposed to attack by atmospheric oxygen in use of a device of which the completed seal-body forms a part. Electrical contact to the rod conductor is then made through the platinum thimble by means of a terminal clamped round the thimble and gripping the platinum thimble against the rod.

By way of example, it may be stated that for forming a seal-body carrying a current of 100 amps., a molybdenum rod conductor of 3 mms. diameter (with head portion 6 mms. in diameter) and a platinum thimble of thickness 0.1 mm. tapering over the last 3 mms. to form a feather edge of thickness about .02 mm., using a molybdenum cooling sheath of thickness 1.5 mms. in the part around the platinum thimble, were found to be satisfactory.

There were two claims and 11 references cited in this patent.

Method of Making Silver Mirrors on Glass. Patent No. 2,762,714. Filed April 10, 1952. Issued Sept. 11, 1956. Assigned to Pittsburgh Plate Glass Company, by Earl R. Smith and John V. Fitzgerald.

(*Continued on page* 238)



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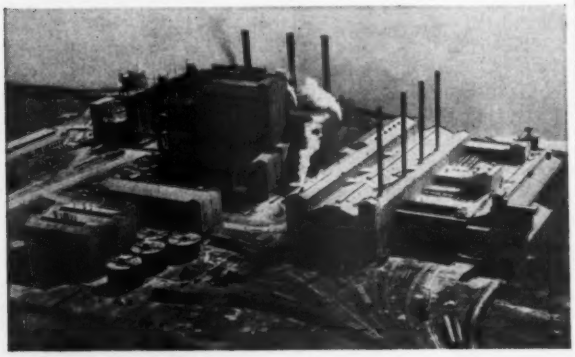
Milestones in Glass Progress

PHOTO COURTESY OWENS-CORNING FIBERGLAS CORPORATION

1946 Noted for their quiet, beauty, and fire-safety features, acoustical materials made from fibrous glass offer a greater reduction of noise coefficients than most ordinary materials. Incombustible, such tiles are light in weight, have low thermal conductivity, dimensional stability, low maintenance requirements.



1890 Michigan Alkali Company, now a division of Wyandotte Chemicals Corporation (North Plant Process, above), was founded by Captain J. B. Ford to supply Soda Ash to the glass industry. Over the years, Wyandotte has maintained its position as a major producer of Soda Ash. Today, it is a working partner, supplying technical assistance and raw-material chemicals to those great companies marking milestones in glass progress.

Wyandotte
CHEMICALS

Michigan Alkali Division, Wyandotte Chemicals Corporation
Wyandotte, Michigan • Offices in principal cities

Founded by a Glassmaker to Serve the Glass Industry

Inventions . . .

(*Continued from page* 236)

This invention pertains to a method of coating objects with a tenacious layer of one of the precious metals.

The primary steps of the invention are as follows. The object to be coated should be cleaned to remove all grease or foreign matter of any sort. The clean glass or metal object is dipped first into a weak solution of stannous chloride ($SnCl_2$). Next it is rinsed in running tap or distilled water; then it is dipped in a weak solution of a precious metal salt, e. g. silver nitrate ($Ag\ No_3$) solution or gold chloride ($AuCl_3$) solution or platinum chloride solution, or iridium trichloride solution or ruthenium trichloride solution or rhodium trichloride solution, or osmium trichloride solution. Finally it is rinsed again in running water.

These four steps are repeated again any desired number of times in the same sequence and there is gradually built up a layer of a metallic appearing deposit. It has been discovered that this deposit does not conduct electricity but gives an X-ray pattern of the metal, the salt of which was used as the second dip in the cycle. This deposit is tenaciously bonded to the object being coated whether the object is a ceramic material, such as glass, or is a metal such as steel or brass.

When the object to be coated is glass, a most satisfactory way of cleaning the surface, before beginning the four primary dip and rinse steps just described, is that of scouring the surface with cerium oxide paste.

There were 27 claims and the following references cited in this patent: 354,343, Pratt, Dec. 14, 1886; 788,912, Just, May 2, 1905; 1,588,510, Wear, June 15, 1926; 1,865,417, Zimmerman, June 28, 1932; 1,935,520, Peacock, Nov. 14, 1933; 1,988,663, Peacock, Jan. 22, 1935; 2,183,202, Misciattelli, Dec. 12, 1939; 2,219,977, Brill, Oct. 29, 1940; 2,249,367, Visser, July 15, 1941; and 2,647,068, Patai, July 28, 1953.

Methods for Treating Glass Fibers. Fig. 2. Patent No. 2,767,519. Filed May 12, 1952. Issued October 23, 1956. One sheet of drawings. Assigned to U. S. A. by Johan Bjorksten.

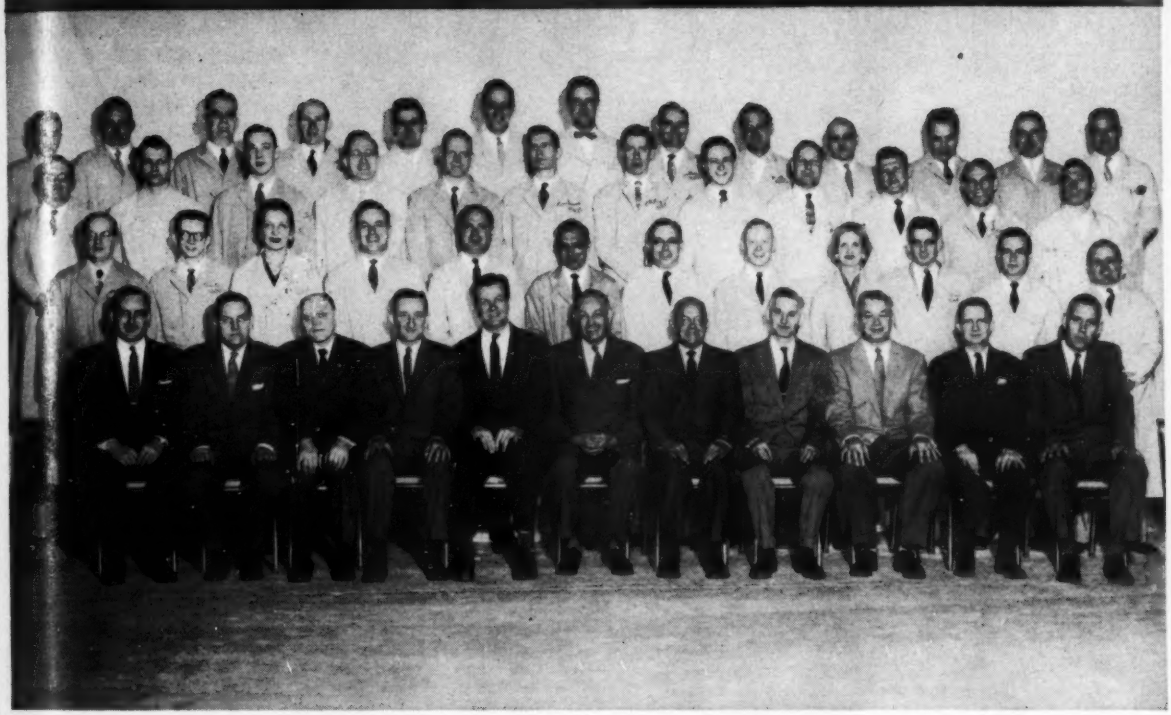
An object of this invention is to apply directly, in the manufacture of the glass fibers, a treatment rendering these glass fibers optimally receptive to adhesion with treatment materials.

1 represents an annual arrangement of nozzles, from which the glass fiber is drawn. (See Fig. 2.) From each nozzle a fiber passes into a vapor space, into which the vapor of the treating agent, for example, vinyltrichlorosilane, is pumped through a tube 2 into a vapor space which the fibers are passing when drawn. In this vapor space 9, which they enter immediately upon drawing, they will combine with the vinyltrichlorosilane, which thus becomes directly attached to the fibers.

This vapor space is partly confined by means of a jacket 3, which can be opened on hinges 4 when desired, for example, to mend or correct a break of one of the fibers. Underneath the jacket is a suction tubing 5, which will take the vapors which receive a downward momentum from the downward travel of the fiber and return these chlorosilane vapors through the pump to

(*Continued on page* 240)

Beyond These Doors...



Beyond these doors is the world of modern ceramic color engineering and manufacture. For it is here in Washington, Pa., that our many technologists command the foremost research facilities in answering countless questions in color application. Here also, our own special methods and equipment process the high-uniformity colors so widely used by all segments of the ceramic industry.

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85-1

Inventions . . .

(*Continued from page* 238)

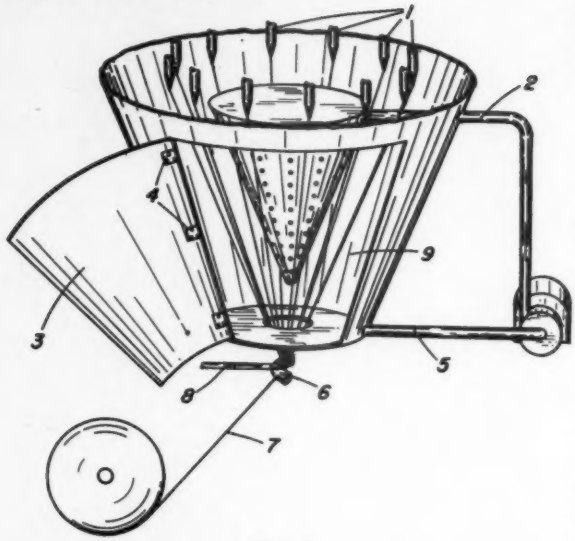

Fig. 2

the said vapor space. The fibers are gathered on a holder 6, from which they proceed as a strand 7.

8 is a supply pipe for a sizing agent which may be starch or any other suitable lubricant and parting agent, but preferably is a suspension of a resin, such as, for example, a polystyrene or polymethacrylate suspension, or the like.

There were six claims and the following references cited in this patent: 2,306,222, Patnode, Dec. 22, 1942; 2,420,912, Hurd, May 20, 1947; and 2,439,689, Hyde, Apr. 13. 1948.

SOLVAY COMPLETES DENSE SODA ASH PLANT

Completion of a new dense soda ash plant at Baton Rouge, La. was announced recently by Solvay Process Division, Allied Chemical. The new facilities more than double previous capacity.

I. H. Munro, president Solvay Process, stated that the plant is now in a position to further extend its service to customers in the southern part of the United States. Shipments by rail, truck or water movement can be made at once from the new installation.

The newest addition to the plant constitutes the fourth expansion of soda ash capacity since Solvay began operations at Baton Rouge in 1935. Other Solvay soda ash plants are located at Syracuse, New York and Detroit, Michigan.

• George P. MacNichol, Jr., president of Libbey-Owens-Ford Glass Company, has been re-elected a board member of the National Industrial Conference Board for a term of one year, it was announced following the 383rd meeting of the board at the Waldorf-Astoria, New York.

Mr. MacNichol has been active in the work of the Board since 1956 when he was elected to its governing body.

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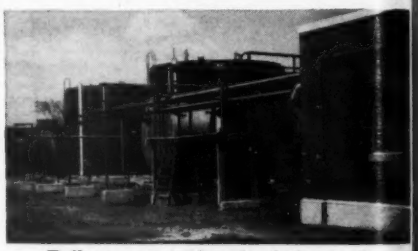

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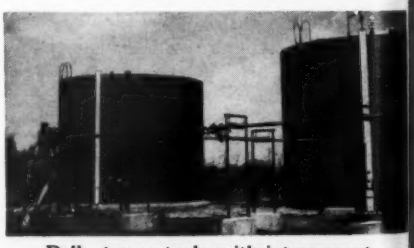

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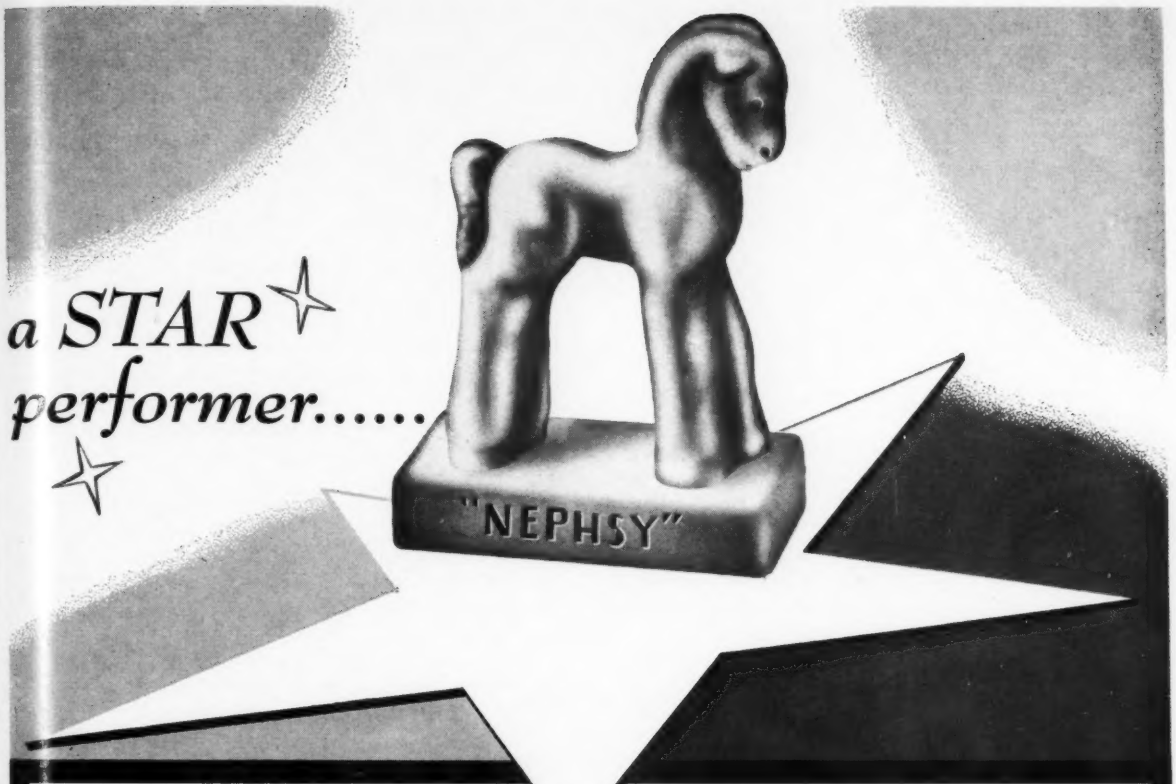

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C. A. BRADLEY AND J. L. KNAPP GIVEN NEW POSTS AT CORNING

Two organization changes at Corning Glass Works were announced recently by A. W. Weber, vice president and director of the Engineering and Manufacturing Staff Division.

Dr. Charles A. Bradley, Jr., was appointed consulting engineer, Glass Melting Operations. James L. Knapp was appointed manager, Glass Technology Dept.

Dr. Bradley joined Corning in 1936 as a physicist, and later served as a glass technologist. He has held positions as supervisor of mixing and melting in "A" Factory, superintendent of mixing and melting for the Technical Products Division, director of Glass Melting Operations and, since 1954, manager of Glass Technology. In his new capacity, Dr. Bradley will act as the company's top consulting engineer in the fields of furnaces, fuels and melting technology.

Dr. Bradley received his doctorate from Columbia University.

Mr. Knapp joined Corning in 1935 in the Works Control Laboratory, and served successively as chemist at the Wellsboro, Pa., plant, production superintendent at Fall Brook plant and the Central Falls, R. I., plant, manager at Central Falls, and since 1954, manager of Glass Melting Operations.

He holds a master's degree from the Massachusetts Institute of Technology and a bachelor's degree from State University College of Ceramics at Alfred University.

BOOK REVIEW

Dislocations and Mechanical Properties of Crystals, edited by J. C. Fisher, W. G. Johnston, R. Thomson and T. Vreeland, Jr. This is a symposium volume, incorporating the knowledge of fifty-four authorities, and is said to provide a full up-to-date account of experimental and theoretical work in the field. The new book records the proceedings of the 1956 international conference at Lake Placid sponsored by the Air Force Office of Scientific Research, Air Research and Development Command, and the General Electric Research Laboratory.

Coverage of the principal methods for observing individual dislocations is one of the book's outstanding features. The more complicated and least understood areas in the field are also reviewed, including such topics as work hardening, recovery, dislocation damping, and fatigue. Present work and outstanding problems that remain to be solved are clarified not only by the basic papers but the inclusion of oral discussions as well.

Dr. Fisher, organizer and chairman of the conference, is with the Metallurgy and Ceramics Research Department of the General Electric Research Laboratory in Schenectady. Dr. Johnston is a physicist for the same organization and Dr. Thomson a physicist and associate professor of physical metallurgy at the University of Illinois. Dr. Vreeland is at the California Institute of technology where he is a physical metallurgist.

This book contains 634 pages. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N.Y. $15.00.

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PHOTO: The technician shown is preparing to measure the liquidus temperature and crystalline phases of glass beads drawn from a customer's batch sample. He is loading the beads into a platinum boat which will be inserted in a liquidus temperature furnace.

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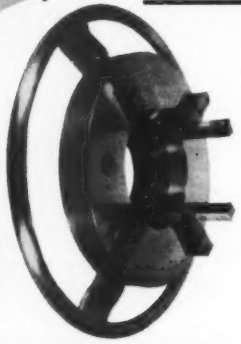

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Research Digest . . .

(*Continued from page* 224)

A crown made of a polished aluminium sheet was erected above the heaters in order to reflect downwards and distribute the radiation. The vertical temperature gradient, as well as the temperature distribution, was measured with a thin-chromelalumel travelling thermocouple. In addition there were similar thermocouples immersed at the thermal barrier in the melting end and the working end.

The tests were started only after the required rate of feeding and the required temperature gradient were established. An orange-red dye was used to visualise the pattern of currents. It was found essential, in order to avoid diffusion, to use a dye which does not dissolve and does not affect the surface tension of the liquid, but forms a colloidal suspension. Several different methods of application of the dye were tried. For quick preliminary tests, thin vertical streaks of the liquid and dye mixture were introduced at several points in the melting end. Continuous feeding of the dyed liquid was found unsuitable because the pattern of flow and in particular the return currents were quickly obscured. The most successful method was to introduce a portion of a dyed liquid at the feed boxes followed by the continued supply of the undyed polymer. In this way the progress of currents could be timed and their pattern observed and photographed.

A double bottom was constructed through which water was circulated in order to obtain different vertical temperature gradients in the model. Cold water circulation gave conditions corresponding to dark green glasses, warm water circulation was used to reduce the gradient (to produce conditions corresponding to white flint glass). The temperature of the circulating water was thermostatically controlled. The vertical temperature gradients to be expected in tanks melting different glasses were calculated on the basis of pilot scale measurements of an overall heat transmission coefficient for those glasses and the thickness and conductivity of refractory and insulating materials used in the tank bottom construction.

The tests covered the effects of several factors of furnace operation and design, such as: distribution of temperature along the melting end; vertical temperature gradient; side wall cooling; rate of melting; distribution of glass load among the 'feeders'; tank depth; position and size of throat; effect of end-firing and cross-firing, etc.

It was concluded that the method offers the obvious advantages of no risk to production, low cost, speed, and a wide range of projects which could be investigated. Perhaps the main disadvantage of the method is the doubt as to how nearly its results correspond to the behaviour of the full-size units. There are some factors, such as the thermal conductivity of tank walls, or the intensity of side wall cooling, which are not included in the similarity criteria and the study of their effects could be only qualitative, i.e. limited to the observation of the changes in the pattern of the currents in the glass.

Some other factors are not represented at all, notably the presence of batch piles floating on the glass. The batch cover must have a major effect on the heat transfer from flames to glass and on the density currents

(*Continued on page* 246)

Here is proof that LU-spar #1 is tops in QUALITY, ECONOMY

Two factors in 20 mesh glass grade spars which can be accurately computed are the feldspar's chemical analysis, and actual net cost per ton of alumina after dollar credits for sand and alkalies have been deducted. The formula below will demonstrate the superiority of LU-spar #1 in chemical value and lower cost.

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Sand: 67.2% x 2000 lbs. x 5.21 tons = 7002 lbs. of silica at .00277c per lb. = $19.40

Alkalies: 7% x 2000 lbs. x 5.21 tons = 729 lbs. alkalies at .0181c per lb. = $13.20

Discount: 2% 10 day discount = .20c per ton x 5.21 tons $ 1.04

TOTAL LU-spar #1 DOLLAR CREDITS **$33.64**

C-(D+E)=F

IN THIS FORMULA WHICH TAKES INTO ACCOUNT SILICA AND ALKALI DOLLAR CREDITS **(A x B = C)**

A = 5.21 tons of spar necessary to make one ton of alumina.

B = delivered price per ton of spar.

C = gross price per ton of delivered alumina.

D = sand dollar credits (% of SiO_2 x 99.5% x 2000 lbs. x 5.21 tons = lbs. of SiO_2 x delivered cost per lb.).

E = Alkali dollar credits (% of alkali x 58% x 2000 lbs. x 5.21 tons = lbs. of alkali x delivered cost per ton.).

F = net cost per ton of alumina.

USING THESE AVERAGE CHEMICAL ANALYSES

	LU-spar #1		SPAR "A"		SPAR "B"	
	ACTUAL	CORRECTED	ACTUAL	CORRECTED	ACTUAL	CORRECTED
SiO_2	67.5 x 99.5*	= **67.2**	67.6 x 99.5	= **67.3**	67.8 x 99.5	= **67.5**
Al_2O_3	19.2	19.2	19.2	19.2	19.2	19.2
K_2O Na_2O	12.0 x 58†	= **7.0**	11.2 x 58	= **6.5**	11.5 x 58	= **6.7**

*% of silica in glass sand. †% of active alkalies in soda ash.

	LU-spar #1		SPAR "A"		SPAR "B"	
Gross cost per ton of Alumina		$110.81		$110.81		$110.81
Less Credits		33.64		31.68		32.11
Sand and Alkali credits	$32.60		$31.68		$32.11	
2% Discount Credit	1.04					
	33.64		31.68		32.11	
NET COST OF ALUMINA		**$77.17**		**$79.13**		**$78.70**

Write us if you would like an actual price computed for you, based on this formula.

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Research Digest . . .

(*Continued from page* 244)

within the molten glass covered by the batch. Attempts made to introduce 'batch' piles, slowly melting or dissolving in the liquid polymer, have been, so far, unsuccessful. For this reason the pattern of currents observed in the models in the 'soaking' zone of the melting end, i.e. near the gable wall, may not be a good representation of the currents .in the corresponding space of a full-size tank.

The results obtained on models should be verified whenever possible by the experiments on commercial tanks, e.g. by measurement of temperatures within the glass, by the use of floaters or radioactive tracers, by controlled changes of the operating conditions, or by the statistical analysis of the data concerning operational factors and glass quality (seed count).

There is much to be improved in the model technique but even with its present limitations the models show relative changes in the patterns, speed and magnitude of glass currents resulting from modifications of design or changes in operation.

B. F. DRAKENFELD SCHOLARSHIP AWARDED FOR SECOND YEAR

The second annual B. F. Drakenfeld Scholarship in the Department of Ceramic Technology, Pennsylvania State University, has been awarded to 1957-58 candidate Charles Kunkle.

Mr. Kunkle, a resident of Cadogan, Pa., and a graduate of Ford City High School, entered Penn State this year.

According to S. J. Courtney, president of Drakenfeld, the $500 grant was awarded this year, as last, on the basis of scholarship, character and need. One of the purposes in establishing the scholarship, according to Mr. Courtney, is to stimulate interest in careers in ceramic engineering and to help assure the industry a supply of trained professional manpower.

CORNING APPOINTS C. A. CRAWFORD AS PYROCERAM COORDINATOR

The appointment of Clark A. Crawford as Pyroceram coordinator for Corning Glass Works was recently announced by the company. He will coordinate the research, production and sales activities required in the manufacture of products made of Pyroceram, the new family of ceramic materials made from glass.

Mr. Crawford joined the company in 1944 as an engineer. In 1952 he was appointed production superintendent at "A" Factory and in 1954 was named manager of the Central Falls, R. I., plant. He then served for two years as manager of the company's Pressware plant in Corning, N. Y. and last November was named Assistant Pyroceram Coordinator. He is a graduate of Duke University.

MODIGLASS OPENS NEW OFFICES

Modiglass Fibers, Inc. has recently opened their new facilities in Florham Park, N.J. These facilities include the company's executive offices, as well as the research department, chemical and physical testing laboratories, research engineering department and technical research.

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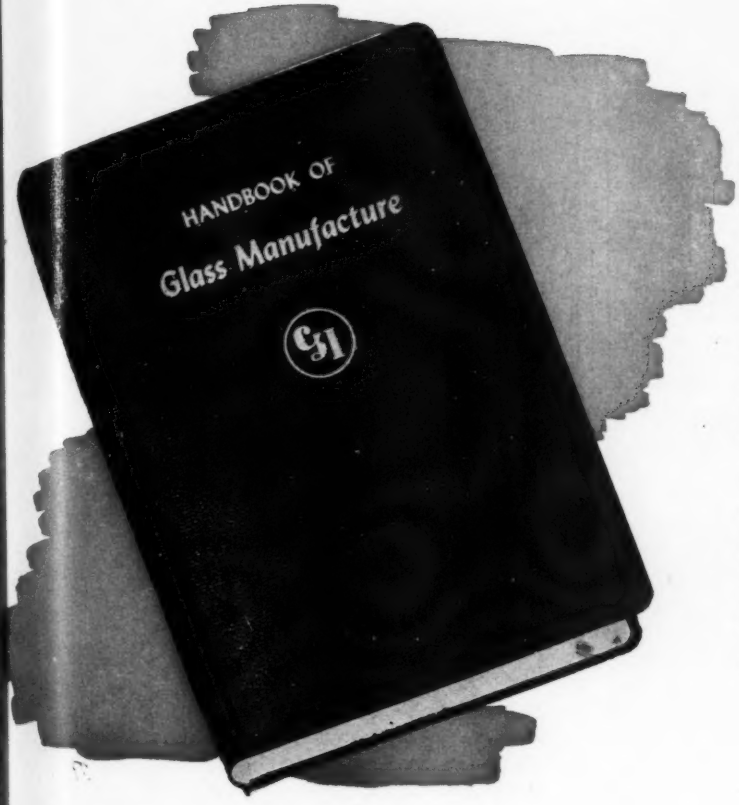
Handbook of Glass Manufacture



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